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GRIFFIN'S SCIENTIFIC TEXT-BOOKS

SIMPLE EXPERIMENTAL HYGIENE, PHYSIOLOGY, AND INFANT MANAGEMENT.

SIMPLE EXPERIMENTAL HYGIENE, PHYSIOLOGY, AND INFANT MANAGEMENT

FOR THE USE OF SCHOOL TEACHERS.

BY

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FOREWORD.

It is a remarkable fact that until recently elementary hygiene was not taught in our schools, and thus the population remained in complete ignorance of the ordinary everyday facts relating to their body functions. The effect of this ignorance was, and still is, calamitous from the point of view of the health standard of the nation, and a needlessly high death-rate has thus been maintained, especially among infants. In recent years, however, better counsels have prevailed, and in most elementary schools simple lessons in hygiene now form part of the curriculum. No doubt this movement was delayed owing to the difficulty of finding suitable teachers, the ordinary elementary-school teacher being then as ignorant of the subject as the lay public generally. To provide special teachers, even had such been available in sufficient numbers, was obviously impossible, so the existing school teachers had to be taught to teach the subject before any further step could be taken.

How was this to be accomplished? There were no books on the subject of a sufficiently elementary and explicit character to enable the teachers to acquire the necessary knowledge for themselves; moreover, mere book knowledge without practical instruction and demonstrations would not have sufficed. Fortunately, a number of highly educated women, realising the urgency of the problem, took up the subject as a specialty, and, having qualified as teachers, placed their services at the disposal of Education Authorities. Thus teaching centres were established where lectures and demonstrations were given to classes of elementary-school teachers. The writer of this book was one of the pioneers in this movement, and that her experience as a teacher, first in Yorkshire and afterwards in Staffordshire, has been put to excellent purpose is evident on every page.

A good elementary text-book for prospective teachers of the subject is a valuable supplement to a course of lectures and practical demonstrations, which is an essential; but such a book is of little value unless it is really informative. Too often elementary books on technical subjects are merely boiled-down editions of comprehensive treatises written for students who have had a general science training. No doubt it is possible by the aid of such a book for a person who has merely had the ordinary training of a school teacher to pack his mind with innumerable bald facts; but more is needed than this to enable him afterwards to impart other than parrot knowledge to his pupils. To place the facts before the student in a form which will enable him to realise the why and wherefore of the doctrines he will subsequently have to teach is by no means easy even to the highly educated expert; and unless that is achieved, nothing is achieved. I venture to suggest that in the following pages the subject has been most skilfully handled from this point of view, and I am satisfied that school teachers will have reason to thank Miss Curwen for coming to their assistance by making such excellent use of her knowledge and experience.

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COUNTY COUNCIL OFFICES, STAFFORD,
22*nd December* 1917.

PREFACE.

This little book has been specially designed for the help of those teachers who, without much acquaintance with chemistry, physics, or dissecting work, are yet desirous, through the use of simple experiments, of making the hygiene lesson appeal as forcibly as possible to their pupils. I have reason to know that many teachers are deterred from such experiments by lack of time to make suitable digests from fuller works, and lack of practical experience in those small matters which may make an experiment successful or otherwise. It is also my hope that the book may prove useful to experienced head teachers by saving them the labour of having to explain and demonstrate to less experienced assistants, and, moreover, that it may prove to be not altogether without some value for the many other workers nowadays concerned with the health and welfare of the community. Where simple addresses on health matters are given to munition and other workers it is hoped that these lessons may prove of use.

Experiments should always be tried beforehand by the demonstrator, so that when the lesson is given there shall be no hesitation. The language is designedly simple where it concerns an experiment, and less so in other cases where it is left to the teacher to modify. The longer chapters will form several separate lessons, and many more experiments can be added if desired. A list of useful books will be found in the Appendix, where also a few practical hints are embodied which may prove of service.

My cordial thanks are given to Dr George Reid, whose generous appreciation of my effort is expressed in the Foreword he has so kindly supplied, and I trust that his encouraging commendation may be justified. If this little book should prove of any real service to the large body of patient and devoted workers for the moral and physical

welfare of the rising generation, it will have accomplished that for which I have hoped.

My acknowledgments for the use of the following illustrations are gratefully made, viz.:—fig. 31, from Dr Leonard Hill's *Manual of Physiology*, and figs. 75 and 76, from Dr Hutchison's *Food and Dietetics*, published by Mr Edward Arnold; figs. 13, 14, 18, 19, and 62, from Macgregor Robertson's *Physiology*, published by Messrs Blackie & Son, Ltd.; figs. 112 and 113, from a leaflet, *Beware the Fly*, issued by the Smethwick Telephone Co., Ltd.; figs. 22, 32, 33, 34, 72, and 73, from Warwick and Tunstall's *First Aid*, published by John Wright & Sons, Ltd.

I desire also heartily to thank my Publishers for the loan of many illustrations, and for never-failing patience during unavoidable delay whilst the work was in preparation and at press.

K. M. CURWEN.

DERBY, *January* 1918.

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SIMPLE EXPERIMENTAL HYGIENE.

PART I.—THE BODY.

CHAPTER I.

SIGNS AND POWERS OF ANIMAL LIFE.

Necessary Apparatus.
A plain india-rubber ball.

Accessory Apparatus.
A high-power microscope.
Tube containing amœbæ.
Glass slides and cover glasses.
Mounted and stained specimens of liver and other clearly defined body cells.
" " " bacteria, etc.

Ever since the beginning of man's life on this earth, he has probably wanted to find out how things were made. He soon discovered that the objects he encountered could be divided into what we now call "organic" and "inorganic": meaning by "organic," animals or plants either dead or alive, or, in other words, things which either have life or have had it once; and by "inorganic," things which have never had life, such as stone or iron. He also picked things to pieces carefully, to see how they were made and what they were made of; or, in other words, he *analysed* them. When he found something that he was unable to pick to pieces, he called it an *element*, which is a word meaning a first principle. He realised that elements were the simple parts of things which were sometimes very complicated. He called the things which he found out were made up of two or more elements *compounds*. He made mistakes, of course, because he had very much to learn. For instance, he said that water and air were elements, simply because he had no means of finding out more about them, and he felt quite sure

that they were made up of nothing else but themselves. Later on, he made the discovery that water is made up of two gases, each of which is an element which cannot be divided into anything else. Therefore water is a *compound*. One gas is called *hydrogen* and the other *oxygen*. He found out that air is a mixture of several gases, most of which are elements. By degrees, over eighty elements have been discovered, out of which the world and the things it contains are built up. Some are gases, such as nitrogen and oxygen; others, such as iron and sulphur, are minerals; and the sciences of chemistry and physics teach us how things are built up and what their powers and properties are.

It is of course not an easy matter to understand about elements and compounds, and a good illustration has been used by a scientific man to describe a chemical compound. He suggests our taking a lump of sugar and breaking it up into the tiniest possible pieces until it becomes fine powder, but each little grain would still be sugar. If, however, we could imagine a very tiny creature like a fairy breaking up the grains finer than we can break them, he would then have in the end what are called *molecules* of sugar. Each molecule of sugar is made up of exactly the same number of exceedingly minute portions of the different elements of carbon, hydrogen, and oxygen. These minute portions are called *atoms*. If he broke up the molecule, even if he only removed one atom, it would no longer be sugar. Atoms of elements are arranged in many different ways to make different molecules, just as with bricks, wood, and stone, in varying proportions, we can build different kinds of houses.

One of the things that has most interested man has been *life*. He has wanted to know how his own marvellous body has been built up, what elements compose it, and what its real powers are. He experimented and analysed and observed, and it occurred to him that, if he could observe a very simple animal and find out how that living creature differed from something very like it that was not alive, he might find out what life meant. Let us see if we can do the same.

Here on the blackboard I will draw the picture of a little animal which we can find in ditch water or living on the roots of the duckweed in a pond. It is so tiny, only $\frac{1}{100}$ of an inch long, that we have to look through a powerful microscope to see it properly, so that I have drawn it very large. It has no colour, and at first, when you examine it, may appear to be only a speck of jelly, full of little grains or granules. If we have a very powerful microscope we may perhaps be able to see that there is a sort of fine network of threads all through the body of the creature, but probably we shall not see this. In this network is the jelly-like substance of which the animal seems composed. This substance is called *protoplasm*, from words meaning "the first substance," and it is called this because it is, in a sense, the

very foundation of life. A little speck of jelly! but this little speck is *alive.* Let us see how we find that out—how, that is to say, it differs from a speck of jelly that is not living. If we watch it as it lies in the water on the glass slide under the microscope, we shall see that it is changing its shape, it is moving. "Ah!" we say, "it is moving, it is *alive.*" But supposing that we have a speck of jelly on a glass slide and hold the slide a little crookedly, it may happen that the jelly begins to move down the slide. Is *it* alive? No. But it moved? Yes, but it did not move *of its own accord.* That makes all the difference; the little speck of jelly had to be *made* to move, but the living one moved when it wanted to do so, because it possesses the power of moving of its own accord, or, in more learned language, *the power of spontaneous movement.*

So we have already found out one of the powers of life. If we watch the little creature we shall see that it is always altering its shape, and, although it has no limbs, yet it puts out parts of its body to one side or the other and draws itself up to the thrust-out portions, or rather seems to flow into them, and so moves forward by means of these false limbs. These thrust-out parts move round and enclose the food the animal meets with and needs. Inside the almost transparent body can be seen a part which is rather less transparent and slightly oval in shape; this is called the nucleus, and is a very important part. Also there may be seen empty spaces or vacuoles. This tiny creature is called an *amœba*, and, as it has no parts or divisions, it is a very simple animal indeed. The body of such an animal is called a cell, and it is described as being a one-celled animal—that is, an animal with only one division or compartment in it (unicellular organism).

FIG. 1.—Amœba resting.
A, nucleus.
B, vacuole.

Supposing that we touch this little creature, what happens? It shrinks away from the touch, it evidently *feels.* Now, a Latin word for a spur or prick is a *stimulus*, and we have adopted that word to mean something which rouses the mind or body to action. If we spur or whip a horse, we stimulate him to go faster and he answers to the touch, or, in scientific language, he *responds to the stimulus.* If he were made only of iron, he could not respond in that way. So we see that the power of movement of a living thing can be altered by a stimulus. The stimulus of a touch is a mechanical one, but we might put some chemical in the water in which the little animal floats and might then see it shrink or alter from the touch of it; it responds, therefore, to a chemical stimulus. If we want to simplify the list of the powers of life, we might say that the first great power of life is the *power of response to a stimulus*, or, in other words, the property of *irritability*; for it is fairly

evident to us now that if a living creature moves of its own accord, it does so because something has *stimulated* or *irritated* it to do so; hunger, pain, weariness, or the desire for exercise, and many other things, stimulate us to movement.

As we watch this little speck in the water we shall see that it seems to come across bits of food, perhaps tiny water-plants, and it flows over and round them until they are enclosed inside its body, and there they are softened and broken up and gradually disappear. They have been *digested.* Every living creature as it moves wears away a part of its body, and that part must be made up again. It is made up by food, and that food must contain the same things as the lost part. What is the amœba made of? To put it very simply, when this jelly-like substance is analysed it is found to be composed mainly of the

FIG. 2.—Moving and flowing round C, a speck of Food.

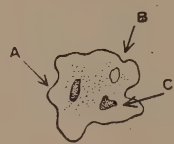


FIG. 3.—Food inside Body.

FIG. 4.—Amœba moving on.
C, waste parts of food left behind.

elements carbon, hydrogen, oxygen, and nitrogen, with a little sulphur. Such a substance is called a proteid substance, and can take various forms; in the case of the amœba it takes a jelly-like form. We have already learnt that this curious matter, with its power of irritability, is called protoplasm; and since all living cells contain it as the foundation of their life, then to find out the powers of protoplasm means the same thing as to say we are finding out the powers of life. Now, since protoplasm moves and wears away, it follows that the worn-out parts must be replaced by the same elements as those composing proteids, since we know that it is a proteid substance. The living cell, therefore, takes in food, splits it up, and out of it builds into its own body the elements it requires (*anabolism*). We do the same thing when we eat our beef and potatoes, or our bread and butter. The amœba casts out of its body all useless matter by the simple process of flowing on and leaving it behind. The matter which it has built up will be broken down again (*katabolism*), and in so breaking down gives the ability to do *work*. This power of taking in and digesting food, building it up into the living tissue of the body, and breaking it down again for working purposes, is another great elemental power of

life, and is called *metabolism*. The power of *assimilation*, or making like, is a part of this power, and is carried out by the power that protoplasm has of always changing its molecules and yet of always remaining the same.

FIG. 5.—Division of Amœba.
A, amœba and nucleus beginning to divide. B, partly divided. C, division complete.

There is another interesting thing we can notice about the amœba, and that is, that as it eats it becomes larger; it can therefore *grow* owing to the power of metabolism. After a time it grows so large that it is very difficult for it to nourish itself properly. It meets the difficulty by dividing into halves. First it grows narrower in the

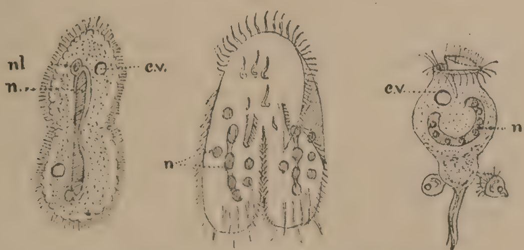


FIG. 6.—Division of other One-celled Animals.
n, nucleus. *cv*, contractile food vacuole.

middle and the nucleus begins to divide; half goes to one side of the cell and half to the other, and the narrow portion becomes so thin that it finally separates entirely and there are two cells instead of one. This power of producing one or more creatures like itself is another great power of life—the power of *reproduction*.

The amœba gets the oxygen it needs largely from the water. We, on the other hand, get ours from the air, and we call it breathing or *respiration*. The power of respiration is a sign of life, but we can put

it down under the power of metabolism. The power of growth can be classed under the power of reproduction.

We can now put down on the blackboard the things which we have learnt about the powers of life, those powers which make all the difference between the living or organic substance and the never living or inorganic one.

Blackboard Summary.

1. Irritability, or the power of response to a stimulus. This includes the power of *movement* and of doing *work*.

2. Metabolism, or the power of taking in and digesting food, of building it up into the body, and of breaking it down again, which enables work to be done. This includes the power of *respiration*.

3. The power of reproduction, which includes the power of *growth*.

We shall hear a great deal about these powers of life, because from them spring all the wonderful powers of the human body, all that makes it differ from what is not alive.

CHAPTER II.

SIGNS AND POWERS OF ANIMAL LIFE—*continued.*

We have seen how the little one-celled amœba moves about in the water and takes in oxygen from it, which is what we do when we breathe in air from the atmosphere. We have also learnt that it takes in food and casts out what it does not require, which otherwise would harm it. All animal cells require fresh air, food, and water, with a certain amount of warmth, and to have their waste matter removed. Although we have so far only spoken of the amœba as the simplest type of animal cell, yet there are many other one-celled organisms, and some of them are not so apparently simple.

When an animal, as simple as an amœba, is in the water it is possible for it to get its food at any part, and also to pass it through to any portion of its body. If it gets so large that this becomes difficult, we have seen that it simply divides into two parts, each part having its own share of the nucleus. But feeding becomes a very different matter when the animal consists of more than one cell. As we go higher in the scale of life we find that cells when they divide do not separate, but may stay close together for mutual help and protection. Just so one or two people in a strange land might perhaps be in great discomfort and danger if they lived separately, but if they join together and have an understanding among themselves they may help and protect each other so long as they can agree wisely together.

But many-celled organisms may find that the inside cells are quite a long way from food and fresh air and also from being able to get rid easily of waste matter. How are they going to get what they need? Here is a diagram of a stage in the life-history of a many-celled organism. It is a hollow ball made up of a great many cells with their edges joined together. I have here a thin india-rubber ball which has a small hole in it, so that, if I like, I can squeeze the air out. I have drawn little divisions or cells all over it with pen and ink, and in the centre of each I have put a dot to represent the nucleus. Each cell in this kind of organism has, as most cells have, a covering round it called the cell wall. Such a little ball can of course get food

and oxygen to each cell quite easily, the wall being only one cell thick. You of course understand that this ball I hold in my hand is absolutely enormous in comparison with the real organisms of which we are speaking, which we have to examine under the microscope. Now, there is another stage in the life of this tiny mass of cells. The hollow ball begins to get a dent in one side, as if a finger had pushed it in, just as I can push this ball in with my finger until I make it

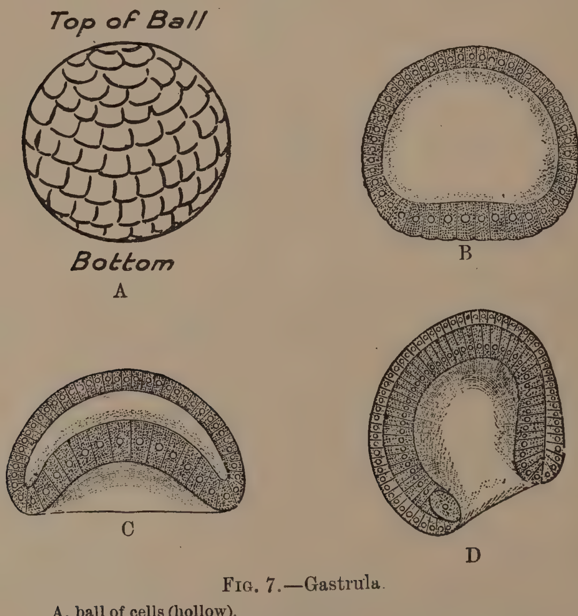


FIG. 7.—Gastrula.

A, ball of cells (hollow).
B, section: lower pole of ball flattened.
C, section through ball now beginning to show a digestive cavity.
D, section: two layers now formed and a digestive cavity.

like a little cup. Are all the cells in the same condition now? No, for the walls are two cells thick now instead of only one, and the cells on the outer layer are not nearly so safe from being hurt by hard objects in the water as are those on the inside. The consequence of this is that a division of work takes place between the cells. It is rather as if the outside cells said to the inner ones: "Look here, this is not right—we are having all the danger; but if we get hurt, you will suffer too. It will be better if we make ourselves harder and tougher on the outside; only, if we do so, we shall not be able to take food in from

the water round us." "Never mind," say the inner cells; "you do the protecting and we will catch the food as it comes in to the inside of our cup, and our soft bodies will eat and digest it, and we will let the digested part soak through us to you after we have had our fair share." "That is a capital plan," say the cells which are living just round the rim of the cup; "but we can help to make things better for us all. Very little water flows into our cup at present, and we shall not get enough to eat for all of us unless we contrive a plan to *drive* food and water inside to you, and we know how we can do it." So they do a very clever thing. The cells on the edge of the cup send out very fine threads made of the protoplasm of their bodies, forming a sort of fringe to each. These fine threads or hairs are called *cilia*. The cilia, being made of delicate protoplasm, are very sensitive and can easily feel things moving about in the water in the shape of food, and they keep on lashing the water by waving to and fro, and so send it in to the inside of the cup with any food it may contain.[1] The inner cells take the food out of it and digest it, and the digested food passes further on and soaks through to all the other cells who are far too busy, some protecting and others lashing the water, to be able to do digesting work, to any extent, for themselves. The power of metabolism is, as we know, possessed by all the cells; nevertheless, those cells on the inside, which practise it most, naturally get stronger at it, as they make it their special business, and this hollow part of the tiny many-celled organism, with its actively digesting cells, is one of the earliest beginnings of a *digestive system*. Our own wonderful digestive organs are simply a development of this. The stomach and the rest of the food tube in the higher animals and man are hollows lined with cells set apart for digesting food and passing it on, after being digested, to cells inside the body. The cells on the edge of the cup get specially good at their work of feeling; that is to say, they develop the first great power of life, the power of response to a stimulus. All cells have it so long as they are alive, as we know, but these become specially sensitive, and they are the forerunners of a *nervous system*. The wonderful nerves and brain of man are made up of millions of cells which have specially developed this power which is possessed so simply by the outer layer of cells in this little cup-shaped bit of life. We must never forget that, whether the animal is a tiny thing like this, or a huge creature like an elephant, it is equally composed of cells which have divided the work among themselves, though, with rare exceptions, every living cell in the body of every animal has the elementary powers of life which we have been studying. They all have the power of irritability or the response to a stimulus, the power of

[1] For illustration of cilia in a bell-shaped one-celled organism, see fig. 6, p. 5.

reproduction, and the power of metabolism, but they possess these powers in varying degrees.

Many-celled animals grow because the cells of their bodies grow larger and then divide, just as the one-celled organism does, only that in the case of the many-celled animal they do not separate. Some, after they have done growing, thrust out little clusters of cells like buds, which eventually break away and become separate organisms. Others set apart special cells for the purpose. Our own bodies are made up of cells which are of many different kinds and shapes, some of which you can see in the diagrams (figs. 8, 9 and 10); but we must never forget that every single cell needs *food*, *fresh air*, *and purification*. Every cell, as it does its work, even if that work is no more than the mere fact of living, has to get rid of waste matter which is the result of the work done. Sometimes the cell breathes out the waste matter, sometimes it thrusts it out, and sometimes it is so far from the surface that other cells have to arrange to carry it away; but, whatever may be the means, the fact remains that waste must be got rid of and the cell purified.

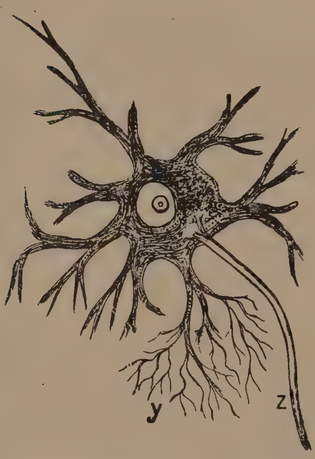


FIG. 8.—Nerve Cell from Grey Matter.
y, fine branches (dendrites). *z*, nerve fibre. Highly magnified.

Besides these tiny animal cells of which we have been hearing, there are other cells, smaller still, which belong to the vegetable world. They are commonly called "germs," though that is not perhaps the best kind of name for them, for the word "germ" is used also to mean much bigger things. The scientific name for them is *micro-organisms*, because they are so small that they can only be seen under the microscope. They are also often called *microbes*. Some of these germs are so small that two thousand of them put end to end would barely stretch across the top of an ordinary little pin, and if a man were magnified to the same size he would look taller by far than the highest mountain in the whole of this country.

There are three main kinds of germs: *yeasts*, *moulds*, and *bacteria*. They are also called by a great number of special names, according to their shapes and habits. Yeasts grow by budding, moulds by little seeds, and bacteria usually by growing larger and dividing into two,

Sometimes bacteria stay together in clumps after they divide, and sometimes they stay end to end and form long strings which look like necklaces under the microscope. Some of the bacteria are round in shape, some are like little sticks (bacilli), and some are spiral-shaped like corkscrews. As bacteria can divide every half-hour, they could grow at an enormous rate if they could get the necessary food, moisture, and warmth. One single bacterium could, in that case, produce about 17,000,000 descendants in twenty-four hours! They cannot do this really, however, for they either cannot get the food or else they become poisoned by their own waste matter.

Although germs are tiny plants to whom the little amœba would be bigger than an elephant, yet they do not and cannot live on the things that plants use. Plants can take the elements of carbon, hydrogen, oxygen, and nitrogen out of the air and the soil in very simple

FIG. 9.—Cell from Lining of Mouth.

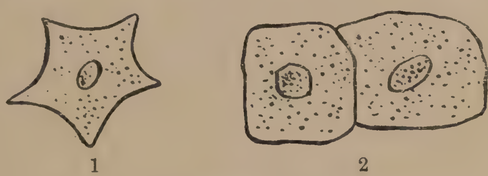


FIG. 10.—1, Star-shaped Cell from Spleen. 2, Two Liver Cells.

compounds and build them up into the more complicated ones which can be used by animal life alone, for this latter cannot live on the same simple food, but has to depend on plants to prepare more complicated ones out of the great storehouses of Nature. Germs take the same food as animals. There are a small number of germs which can cause ill-health in living creatures when they effect an entrance and are not at once destroyed by the guardian cells of the body, but the great majority only begin to grow when life is extinct. They are present nearly everywhere, in the air and the soil, on the leaves of plants and the feathers of birds, as well as on our skin, our clothes, and our furniture. Most of them are not only quite harmless to us, but are our very good friends.

As soon as the life is out of the leaf or the bird, the germs can begin their great work of turning them back into the simple compounds, which pass into the air and the soil, to be used up again once more by the plants. It is a never-ending circle in which nothing is ever lost or wasted, and what was a butterfly one day may, later on, become part of the substance of a rose. All decay is the work of germ life,

which pulls to pieces what is no longer living, and is always helping to purify and get rid of waste matter. We are helped by these tiny cells in all sorts of wonderful ways, but we do not want them in the wrong places, where they may do us harm. We shall hear a great deal more about them in later lessons.

From what we have learnt we can see that, though the cells may do special work, they nearly all have the same powers and needs. It is the same with people in a house, everyone has to eat and drink, but everyone does not do the cooking. Everyone needs the house to be kept fresh and sweet, but everyone does not do the cleaning. People living together find that it is best to divide up the work, and that the house is better managed and more comfortable if each one has a special thing to do and does it, and, by getting practice in doing it, comes to perform it specially well. The house in which it is no one's duty to cook, or sweep, or wash, or make the beds, or do the marketing, would be a very uncomfortable one to live in; the meals would be badly cooked and very unpunctual, and there would be confusion, loss of time, quarrelling, and untidiness. In a well-ordered house each one does his or her share; and if that duty is neglected, then everyone else suffers for it; but if the duties are well done, then all benefit.

It is always so in the bodies of plants and animals. Every cell or collection of cells has its own work to do, and, if it does not do it, the body may fall sick and even die. No collection of cells can be perfectly well unless all do their work. No town can be properly managed unless the citizens do their duty towards it. The slovenly, dirty man or woman is a danger to everyone. Every member of a community should do his or her duty to that community, and everyone should have fair play to help him or her to do it. That is the rule of the healthy cells of the body, and a very good rule it is.

We will now put on the blackboard the new things we have learnt:—

1. All animal cells need a certain amount of food, warmth, and fresh air, and to have their waste matter removed.

2. Many-celled animals divide the work among the different cells, and so gain strength and protection.

3. If some of the cells of the body of an animal refuse to work properly, then the whole body may suffer seriously.

4. If the citizens of a city, or the members of a nation, refuse to do their duty, then the city or the nation will soon suffer.

"England Expects Every Man to Do His Duty."

CHAPTER III.

LESSON ON THE SKELETON.

Necessary Apparatus.

A long, slender rib-bone, which has been at least a week in *strong* hydrochloric acid (spirits of salts) in the proportion of one part of acid to seven parts of water.

A piece of bone burnt in a clear fire, while held in an iron spoon, and reduced to the mineral portion only. If possible, reduce to whiteness.

A fresh long bone split open.

Any available bones as specimens.

A large diagram of the skeleton.

A piece of fairly strong paper, and elastic band or string to fix it when rolled up.

A weight to hang on the roll.

A broad ribbon or tape for suspending the weight.

A rough imitation of the spinal column, made with seven small reels for the cervical vertebræ, with pads of felt between, twelve large reels, and five still larger, all strung on cord. The cord illustrates the spinal marrow running through the spine.

Note.—Prepare and test all experiments before the lesson. Have everything at hand. Compel the pupils to make the observations. *This is most important.*

We have been learning about the wonderful way all the little divisions of the body, which we call "cells," do their work, and to-day we must try to see how we can help them. Here is a long piece of bone. How hard it is, how smooth and polished! Yet this hard substance is all made out of little cells. Let us try to find out how bone grows—for you are growing, are you not? And so your bones must be getting thicker and longer.

There is in the body a substance or tissue called cartilage or gristle; there are several kinds of it. We have here a drawing of a kind called hyaline cartilage (fig. 11). There is a groundwork, and lying in that groundwork are little cells. Only the cells are shown in the diagram. Cartilage is developed by cell life. Bone starts its life-history in the shape of gristle, but the cells gradually take mineral salts out of the blood and turn the gristle into bone.

Here is a picture of bone (fig. 12), and the citizen cells of which it is composed have had the hard mineral salts brought to them by the blood, and if they are properly fed they take the salts and build them up into

their own bodies, and by degrees, as we have learnt, make themselves strong and hard. A very young child has in its long bones only the shaft made of real bone; the ends are still gristly, and are full of soft growing cells, which increase and multiply and make the bone grow in length (fig. 13). This end gradually hardens and becomes true bone. For many years, however, there is a line of gristle between the shaft of the bone and its end, and as long as this is so the person can grow taller (fig. 14). Very little children are sometimes seized by grown-up people by their hands and swung round for fun. This is not a good thing to do, especially with a heavy child, for it might separate the shaft of the arm bone from its end, and then the bone could no longer grow in length. You will never swing your baby brothers and sisters by their arms now that you know this, will you? It might hurt them very badly. A bone grows in thickness from a kind of skin or membrane which grows round it (the periosteum; show this, if any is left on the fresh bone). Cells from the inner side of this become bone and form layers of hard bone cells round the shaft. If this skin is stripped off, the bone cannot grow properly. Here is a rib-bone which has been steeped for a long time in acid. The acid has dissolved out the lime salts and left behind only the soft gristly part. Look! I can bend it double, or even tie it in a knot, and it will not break, and yet it looks like an ordinary bone. Here is another bone which has been burnt in the fire. Can I bend this one? No, it snaps at once or perhaps crumbles to bits, and if we put it into strong acid it dissolves completely and nothing remains to be seen. What has happened? We have burnt in the fire all the soft, gristly part and left only the hard mineral salts, and they have dissolved away, as they did when we put the fresh bone into acid, only then we had the soft parts left and could see the shape of the bone. Now we have burnt it all away, the soft part with fire and the hard part with acid. If we evaporated the acid we should find the salts at the bottom. If we weigh bone before and after we treat it in this

FIG. 11.—Cartilage Cells.

way, we can easily find out how much soft, gristly matter is present and how much hard. Bones contain about two parts hard matter and one part soft matter.

Children's bones are softer than those of grown-up people, and therefore children grow crooked easily if they sit badly.

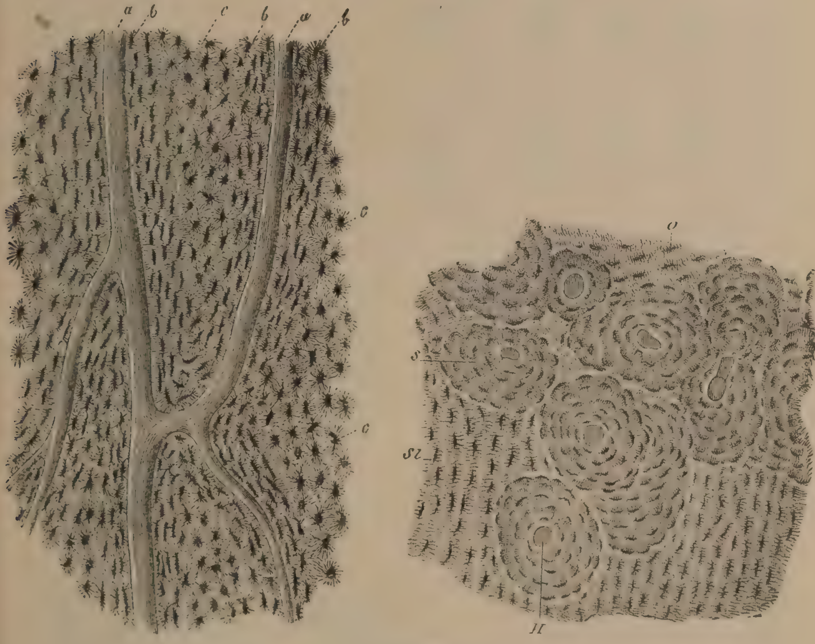


FIG. 12.

A. Longitudinal section of Bone.

a, Haversian canals.
b, lacunæ, seen from the surface.
c, ,, ,, from the side.

B. Transverse section of Bone.

H, Haversian canals.
sl, interstitial lamellæ.
o, lacunæ with canaliculi.

How do the bone cells get fresh air and food? The blood brings it to them. Long tubes, called blood-vessels, burrow in through the walls and spread out between the cells and bring them nourishment. Look at this long bone. Do you see little holes in it? This is where the blood-vessel goes in, carrying fresh air and food. Blood-vessels which carry fresh air, as well as blood, are called arteries, and start from the left side of the heart. The cells take out the food, mineral salts, and fresh

air, and give up their waste, impure matter to the blood. Veins carry this blood away to the right side of the heart and finally get rid of its impurities, if the lungs, kidneys, food tube, and skin are doing their work. If these are not working properly, then the bones do not get such good pure blood and do not grow as well as they ought to do. If we breathe badly, have dirty skins, eat bad food, and neglect to get rid every day of waste matter from our bodies, we cannot expect the bones to grow well. Playing games, running, leaping, skipping, physical exercises are all good, because they make the blood go quicker round the body and cause it to take in more food and fresh air. Exercise helps to nourish the busy cells, and also makes them better able to get rid of waste matter. Sometimes we see little children with bones that are too soft. This often happens when babies are deprived of sunshine and not given plenty of milk, but are fed on wrong kinds of food, poor in fat and full of starch. Starch will not make bones, nor can babies digest it, and the cells become so starved for want of proper food that they are unable to take the mineral salts out of the blood and fix them properly and so get as hard and firm as they ought to do. There is nothing like milk for babies, as it feeds the cells well. It is strange to think that the industrious cells making our bones hard for us need fresh air, good food, exercise, and cleanliness to help them, is it not? But now we understand why it is that dirty, neglected children are so often sickly, weak, and undersized, and have soft bones. When you are grown up you must try to see that all the children you have anything to do with have a chance of getting good strong bones. In the meantime, take good care of your own, and learn to breathe properly, eat good food, and take plenty of exercise.

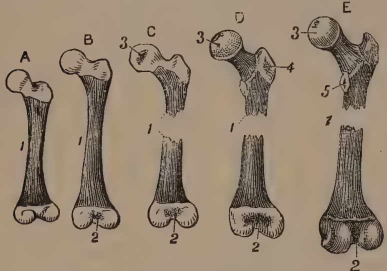


Fig. 13.—Centres of ossification of thigh-bone.

A, both ends still cartilage, (1) shaft alone true bone.
B, at (2) a small amount of hard matter begins in lower end.
C, aged one year, (3) second bony deposit.
D, continuation of deposits.
E, further continuation till both ends become bone.

Fig. 14.—Longitudinal section of Bone.

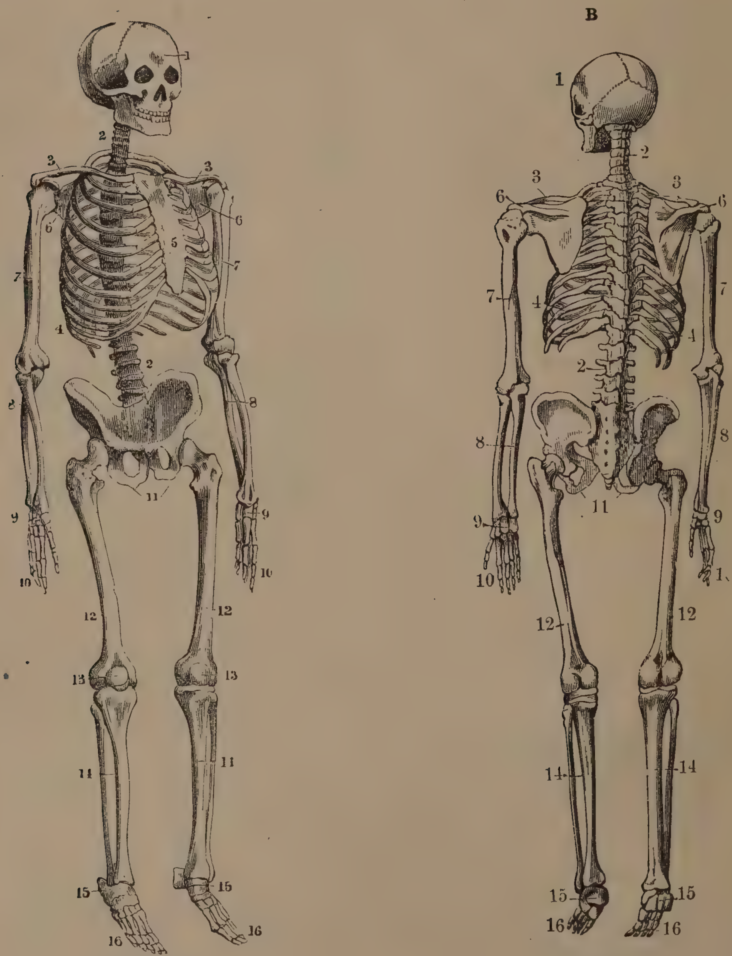
Now we must look for a moment at the inside of this long bone which has been split open. Is it solid all through? No, it is hollow in the middle, and the hollow has marrow in it. The red marrow of long bones helps to make blood. Why are long bones hollow? Let us make a little experiment and see if we can find out the reason. Here is a piece of strong paper, and I will roll it up into a tight but hollow roll like a long bone. Now I will hang a fairly heavy weight on to it by a fairly broad band, while its two ends are supported (see fig. 15).[1]

Does it bear the strain well? Yes, very well. Now let us take the same piece of paper, or a piece exactly the same size, and fold it into a flat bar instead of a roll, and support it in the same way and hang the same weight on. What happens? It doubles up, and if it were brittle like bone it would evidently break. What does that show us? It shows us that the same amount of material bears far more weight if hollow than if flat. If we wanted to make the flat piece bear the same weight, we should have to make it very much thicker, and therefore it would be much heavier. Now we understand that Nature has made the long bones of our limbs as light as possible for their wonderful strength.

FIG. 15.—Roll of paper, supported on books, bearing a heavy weight without bending.

There are several kinds of bones: some are flat, others are round, and others again are very irregularly shaped. Let us first of all look at this picture of a skeleton (fig. 16). Here is the head part, which we call the skull. How many bones are there in the skull? Perhaps you think that there can only be one, but there are really twenty-two; eight of these are beautifully fitted in together to form a strong box for the brain, and the fourteen others form the face. Notice the sockets for the eyes, and the openings for the nostrils and the mouth. We can move many of our bones, because they are not firmly fixed to each other but are loosely connected by joints, such as the knee, elbow, and hip joints. We find, however, that the bones in the skull fit into each other tightly, and therefore cannot move at all. There is nevertheless one bone which has a hinge-joint, like the knee or the elbow. Can anyone tell me which bone that is? I am using the joint now, and so will you be when you answer me. It is the jawbone. That is the only movable joint in the head. In very tiny babies there are some places on the head where the bones have not yet quite grown together. There is one

[1] The band as shown in the illustration is too narrow.



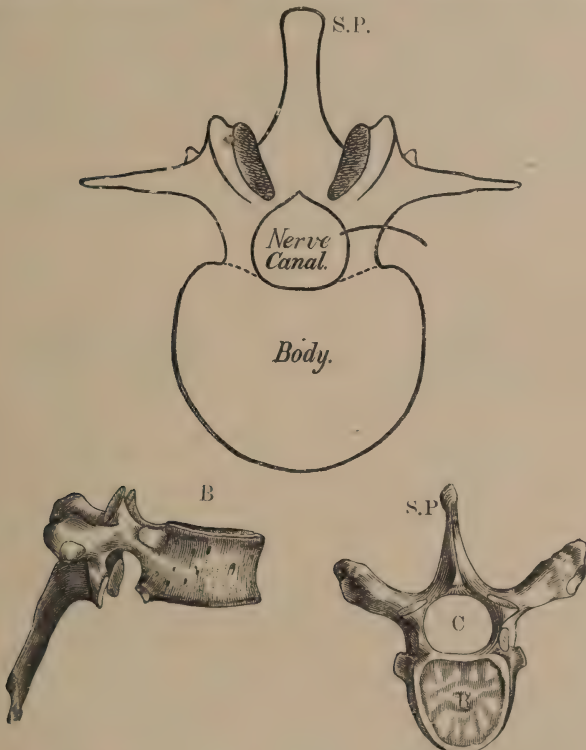
Front view. Back view.

Fig. 16.—Skeleton of Human Being.

1. Skull.
2. Spine.
3. Clavicle.
4. Ribs.
5. Sternum.
6. Scapula.
7. Humerus.
8. Radius and ulna.
9. Carpal bones.
10. Metacarpal bones.
11. Pelvis.
12. Femur.
13. Patella.
14. Tibia and fibula.
15. Tarsal bones.
16. Metatarsal bones.

such place on the top of the head, where only soft tissues cover in the delicate brain, so we have to be very careful to protect babies' heads and see that they do not get hurt in any way.

The skull is balanced on the backbone, which is made up of several



From the side. Transverse section.

Fig. 17.—Dorsal Vertebræ.
S.P., Special process. C, Nerve canal. B, Body.

little bones, each called a vertebra ; when we talk of several, we call them *vertebræ*. There are thirty-four of these bones, but in grown-up people ten of the lower ones grow together to form two big ones, therefore they have only twenty-six. Here is a picture of one. You see it has a flat body and some pieces sticking out at the sides, and one sticking out at the back. If you pass your hand down someone's backbone, it is

these pieces at the back which you feel. The two top vertebræ are very peculiar. The one before the top has a little piece of bone, like a short finger, sticking up in front, and is called the *axis* bone (fig. 18); the next one above has no body. Here are pictures (or models) of both. This last bone is called the *atlas* bone (fig. 19), and the head rests on it, and it itself fits on over the pivot bone, just as you sometimes see in the hinge of a gate how a ring of iron fits over an iron pivot and the gate can swing open. If we had not got this pivot joint we should not be able to turn our heads from side to side. The jointing also of the head with the atlas bone makes us able to nod our heads and bend them backwards.

After the seven bones in the neck come twelve bones in the back itself, and into these the ribs are jointed. How many ribs have you?

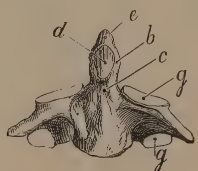


Fig. 18.—Axis Vertebra. Front view of Axis.

b, pivot. *d* and *g*, articulating surfaces.

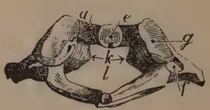


Fig. 19.—Atlas Vertebra, seen from behind.

e, articulating surface or joint for front of pivot bone (fig. 18). *k*, position of ligament. *l*, nerve canal.

Twenty-four, twelve each side. The first seven are called *true ribs*, and they join on to the vertebræ behind and into the breastbone in front, but they are not bone all the way. Before they pass into the breastbone they are soft and gristly. The breastbone in children has six pieces, all joined together by gristle, full of growing cells. If we stoop over our desks, our ribs and breastbone do not get a proper chance of growing as they ought to, partly because of the effect of the position, and partly also because we cannot breathe deeply in that position, and therefore the lungs do not swell out the ribs, for the lungs are inside the bony cage formed by them. It is also easy to make the breastbone grow crooked if we sit cramped up. Notice that the next five ribs on each side are different from the others in the way three of them join their gristly parts together before they enter the breastbone. Do you notice anything else? Yes, the two last ribs are very short, so short that they do not reach the breastbone at all. These last five ribs are called the false ribs, and the two last are also called the floating ribs.

Notice how the ribs slope away. If silly girls tight-lace, these ribs come close together, and then the poor lungs inside, and other organs as well, cannot do their work properly, as they have not got enough room.

Now we come to the lumbar vertebræ, much thicker and stronger. Why? Because they have more weight to support. There are five of these. Next comes a wedge-shaped bone (the *sacrum*), consisting of five bones welded together, and then a little tail-like bone (the coccyx), made up of four tiny bones joined together. Notice the curves in the backbone. A baby's backbone has not got those curves, and the little bones are very soft. A baby ought not to be made to sit up till it is seven months old. Your backbones are growing, and if you sit crooked they are growing crooked all the while. If you stoop over your desk you get round-shouldered. If people are very round-shouldered we call them hump-backed. You get round shoulders because your backbone is growing crooked. If you sit sideways at your desk your backbone is twisted. I will draw some lines on the blackboard showing you the proper four curves of the backbone, and also the curve in the part which makes round shoulders from stooping; we will then imagine that we are standing behind someone and watching his backbone, and I will draw a curve showing one which is twisted. Standing with all one's weight thrown on one leg will twist the backbone and make one hip grow higher than the other, besides being a very ugly position. It is very ugly to see grown-up people sit or stand or walk badly, but at least they have done growing. Boys and girls in school, however, are growing all the time they take up these wrong positions, and therefore tend to grow into those shapes. Sometimes desks are wrongly made, and in any case sitting a long time is not good for growing children; so that is why we make you stand to read and why we give you special exercises after a sitting lesson, or whenever we think you need change of position, so as to correct the harm which might be done by bad postures.

Between the bodies of each vertebra of the spine is a pad of cartilage, and each vertebra has a bony ring which fits over the ones above and below. A long hollow space through the backbone is thus formed; in this runs the spinal marrow, which in a sense is part of the brain and joins it inside the skull. (Here show diagram or model of spinal column.)

Notice the collar-bone or *clavicle* in the diagram (fig. 16 (3)), how it passes from the shoulder to the breastbone; and notice also the big, flat shoulder-blade behind. Notice, again, the way the arm-bone is jointed into the shoulder. The top of the long bone of the arm has an end shaped rather like a ball, very smooth, and covered with gristle (cartilage): this fits into a shallow place like a saucer, in the shoulder, and is held in place

by strong bands of tissue called ligaments, which pass from bone to bone. The inside of the joint is lined with delicate membrane which is made up of little cells, whose business it is to make a fluid from the blood, to oil the joint and make it work smoothly. The ball moves about in the saucer as you move your arm. In how many directions can you move your arm? Up and down, backwards and forwards, sideways and round and round. This is such a wonderfully easy joint that you can move the limb in every direction. When people dislocate their shoulder, the ball rolls over the edge of the saucer and then they cannot move their arm until it is put back again. This kind of joint is called a cup-and-ball joint. We have only one bone in the upper arm. At the elbow we have another joint, not a "cup-and-ball" joint like the other, but a "hinge" joint. In how many ways can you move your forearm (lower arm)? As many ways as the upper arm? Try and see! Hold your upper arm firmly so that you do not use the shoulder-joint but only the elbow-joint. How many ways can you move? Backwards and forwards, and sideways, but not up and down, or round and round. So a hinge-joint is not quite so movable as a "cup-and-ball" one.

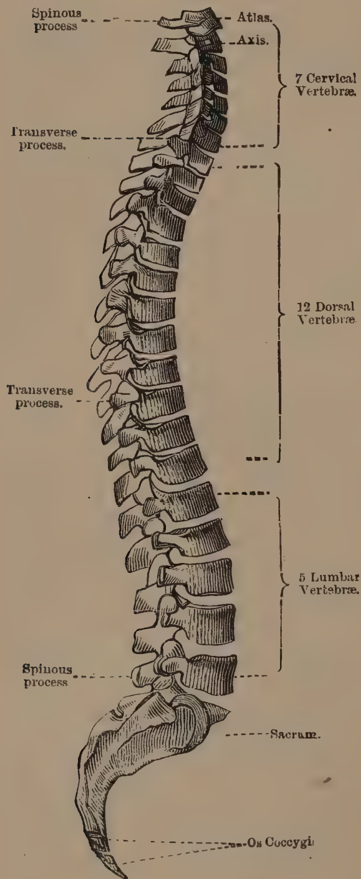


Fig. 20.—Diagram of Spinal Column.

How many bones are there in the forearm? Two. One of these bones is jointed on to the side of the other in such a way that it rolls round on it. That is why you can turn your hand round. There are eight little bones in the wrist, and five in the palm of the hand. How many has the thumb? Two. How many have the fingers? Three each. What kinds of joints have

the fingers and thumbs got? *Hinge-joints* like the elbow, but the bones in the wrist are not perfect joints as are the elbow, shoulder, and knee; these bones can only glide about a little on each other. Such joints are called "gliding joints," and give great freedom to the wrist. The lower limb is made up of the thigh and the leg bones. How is the thigh-bone joined on to the hip-bone? By a "cup-and-ball" joint, a very strong one, for the "cup" is really like a cup, it is so deep, not like the shallow saucer-like cup at the shoulder. In consequence of this it is very difficult to get a dislocation of the hip-joint. The head of the thigh-bone has a special ligament, too, which binds it in very firmly to the middle of the cup. The thigh-bone is the longest bone in the body. Here is a picture of the hip-joint cut in half (fig. 22). Then comes the knee-joint (fig. 23). What kind of a joint is this? It is a hinge-joint, and the joint is protected in the front by a little flat bone, called the knee-cap. Otherwise we should easily inflame the joint when we knelt, by the hard pressure on it. Even with the knee-cap to protect it, the joint sometimes suffers if people have to kneel on hard things to do their work. It is better for them in that case to have a soft pad to kneel on. The leg has two bones, like the forearm. One in front is the shin-bone, and is rather three-cornered, with one of the corners in front. That is why it feels so sharp, especially as it has very little else but skin covering it. The other is a thin bone called the splint-bone. The ankle has seven small bones, and the body of the foot has five, while the big toe, like the thumb, has only two, and the little toes three. The foot is arched underneath. An arch is the strongest thing in architecture, and the foot has to support the weight of the whole body. If we get the arch of our foot flattened, the foot aches and is very painful, and we cannot walk properly. People who have to stand a great deal sometimes suffer from flat-foot. They ought never to neglect their feet if they begin to ache from standing, for they can be cured easily by proper care. We take special exercises which are good for the muscles and ligaments of the foot. Rising on tiptoe

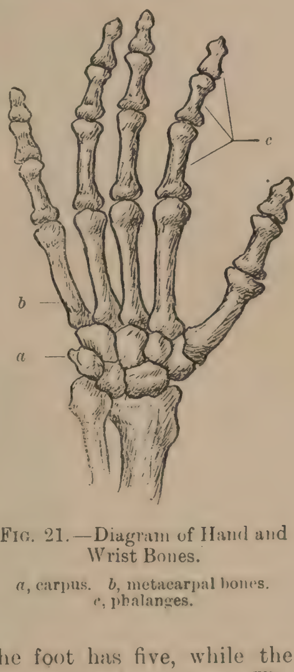


FIG. 21.—Diagram of Hand and Wrist Bones.

a, carpus. *b*, metacarpal bones. *c*, phalanges.

is one of them; this helps to strengthen the band or ligament which binds the arch together. It is the undue stretching of this band which

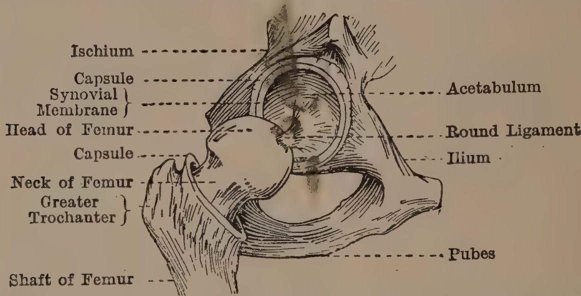


FIG. 22.—Hip-joint, showing the head of the Thigh-bone or Femur detached from its socket but still adhering to it by means of the round ligament.

flattens the foot. Arab women are very proud of the arch under their feet, and if they want to describe someone with a very well-arched foot, they say it is so arched that water could run under it without

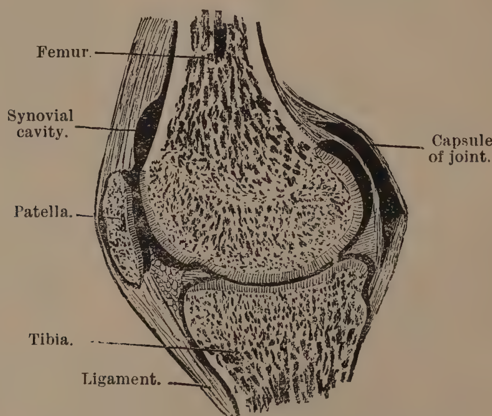


FIG. 23.—Lateral view, section of Knee-joint.

wetting the middle of the sole, just as a stream runs under the arch of a bridge. But the most arched foot really touches a little bit at one side of the middle part. If we want to be sure that our arch is a good one, we put our bare foot in water and then stand on a piece of

something smooth and dark such as brown paper, and so we get a print. If the whole sole shows, our feet have not got good arches.

Now we will put on the blackboard some of the things which we have learnt :—

1. The skeleton is the bony framework of the body.

2. Children's bones are soft and growing, therefore wrong attitudes may make them grow crooked.

3. Bone cells harden by taking salts from the blood, but cannot harden properly unless the blood brings them proper food and plenty of fresh air.

4. If babies are to grow up strong-boned and healthy, they should get milk to drink, not starchy foods to eat.

5. Dirty skins and irregular habits, bad air and sluggish ways help to poison the bone cells.

6. Clean skins, regular habits, fresh air, and deep-breathing exercises clear away poisons from the bone cells, and help to make people tall and strong.

CHAPTER IV.

THE MUSCLES.

Necessary Apparatus.

A band of paper, about three inches wide, and long enough to pin round upper arm. Pin together when on, at top *and* bottom.

Two pins.

Two long, narrow pieces of cardboard.

A pivot or paper-fastener.

A small piece of beef, boiled to rags, or else a small piece of corned beef.

Large diagram of muscle fibre, drawn on blackboard.

Show also connective tissue.

Note.—Have everything ready at hand and in the right order. Do not tell the children the observations. Make them observe what happens and tell *you*. *This is important.*

We have learnt now about bones and about joints, but how is it that we can move our bones, and walk, and work, and feed ourselves? Can any bone move of its own accord? No. What moves it, then? Let us see what we can find out about this matter. Here is a narrow band of paper, two or three inches wide. I will pin it tightly round the middle of my upper arm. Now I will take this heavy book in my hand and bring the book up to my shoulder by simply bending my elbow. Has anything happened? Yes, the paper band has burst. What does that show? It shows that the arm must have become thicker than it was before, and so much so that it has burst the paper. Here I have a very simple model. It is merely two narrow pieces of cardboard, joined together by putting the two ends one over the other and running a paper-fastener through. Now we have something which is rather like one of our own arms. The top piece of cardboard represents the upper arm. The place where the pieces join is the elbow-joint, and the lower piece is one of the two bones of the forearm (the radius). See! I can bend it up and down. Try to imagine it is my arm which I bent just now. How did I bend it? Supposing I pin this little strip of elastic right up on the top of the bone, and pin the other end on to the radius bone, and then supposing I make a knot in the middle of the elastic, or simply pinch it up in my fingers, while I hold the top piece of cardboard firm, what happens? The lower arm moves up, the

elbow bends, and the hand part is brought near the shoulder part. Now in my arm I have something which is called a *muscle.* A muscle is a band or bundle of flesh, and that band is fixed at one end to an immovable part of the shoulder and at the other to the forearm, just below the elbow as the elastic was. Then a message comes down a kind of telegraph wire, called a *nerve*, which lies buried in the muscle. The message comes from that central office inside my head which is called the *brain*, and this message has a curious effect on the muscle and causes it to become thick in the middle; but since the two ends are made of tendon or, as they are popularly called, *leaders*, and have no power of altering their length, the result is as if an invisible hand tied a knot and my forearm is therefore pulled up. The muscle to which this happened is called the *biceps* muscle. When I straighten my arm it is because another muscle at the back pulls it down again and the biceps relaxes. The muscle at the back is called the *triceps.* Here is a picture of the biceps and triceps muscles, and the bones of the arm. Notice the cords at each end; those are the tendons. The leaders dive right into the bone, and are very firmly fixed and very strong. You can easily feel your muscles getting short and thick when they do work, by putting your hand over them. How do you move your jawbone when you eat? By muscles. Lay your fingers along near the edge of your cheek not far from your ear and pretend to bite something. What do you feel? You feel something swell up. When does it swell up? When your teeth are closing or separating? When they are closing. What does this muscle do then? It pulls the lower jaw up. The harder the thing is which you have to bite, the heavier the thing is which you have to lift, so much the thicker and shorter will these muscles get in order to overcome the resistance.

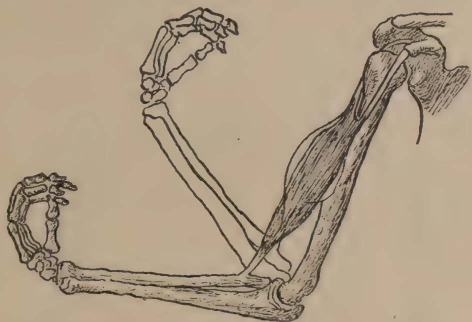


Fig. 24.—Diagram showing Biceps and Triceps Muscles in repose and in action.

Muscles are of many shapes and sizes, and there are about 240 of them in the body. There are big muscles in the back which help to keep us upright, and others in front which help us to bend forward. We have muscles at the back of the thigh which help to bend the

knee, and others in front which help to straighten it. Other muscles help us to bend our necks and straighten them again. Muscles which cause bending at a joint are called *flexor* muscles, those which straighten a joint are called *extensor* muscles.

Here is a little piece of boiled beef-steak. It is a piece of muscle taken from an ox. It has been boiled a long time. What does it look like? A bundle of little strings. These strings are called fibres. How long are they? About $1\frac{1}{2}$ to 2 inches long. Each one of these fibres is really an altered cell, and its nucleus has divided up into several small ones. Now, if we examine these fibres under the microscope, or look at this diagram of them (figs. 25 and 25A), do we notice anything at all peculiar about them? Yes, they are striped across. If also we take a fine needle and tease one out, what do we see if we hold it up against the light? We see that lengthways it can be separated into tiny threads. How fine are they? Far finer than hairs. The fibres can be separated across into discs, where the little fine stripes come. Muscle made like this is called *striped* muscle.

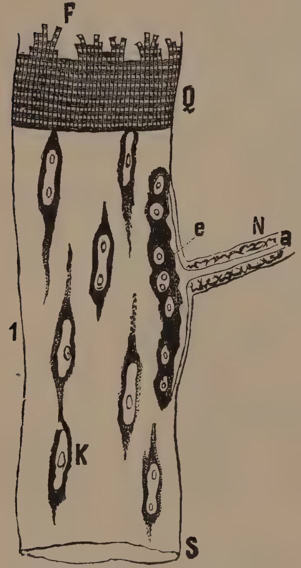


FIG. 25.—Diagram of part of a Striped Muscular Fibre. Magnified.

FIG. 25A.—Isolated Muscular Fibrillæ.

Each fibre has a very delicate sheath of fine tissue, which wraps it round, and several are joined together in bundles and again wrapped round, and these bundles are joined together to form one big bundle, which is the whole muscle itself and, like the little bundles, has its own delicate but strong wrapper round it. The fibres are joined in end to end when the muscle is a long one, and at the end of the muscle they become tendon and join the bone. These muscles are red, so we call them *red, striped muscle;* but as we can move them voluntarily, that is, by the power of our will, we also call them *voluntary muscles.*

There is another kind of muscle which is white; it is found inside the body. In it the cells have not been altered into fibres, and are long

and spindle-shaped, as in the diagram (fig. 26). They are joined together in flat bands, not round bundles. The walls of blood-vessels are partly made of them, the food-tube also, and various other organs. They are not striped and are not under the control of the will, so they are *white, involuntary, non-striped muscle.*

Living muscle has wonderful powers. It has the great power that we saw in the little one-celled animal which we heard about in the first lesson—it can answer to a stimulus, either the stimulus of a touch or of a chemical. The stimulus may be a message from the brain down a nerve, and then the muscle fibres get shorter and thicker and pull on the bones. They relax and rest between each contraction, of which there are separate waves. If one stimulus follows another too rapidly, the fibres have no time to relax and the muscle suffers from cramp. This sometimes happens from a poison being in the blood. One kind of poisoning may come from putting dirty things, like cobwebs, on to open wounds, and is called *lockjaw.* Cramp may also come from not being careful to get rid of waste matter from the body and also from getting overtired. Muscles do work by their power of getting shorter (contraction). They also have another power. When you are cold you often run about to get warm. Why do you get warm? It is partly because in doing work the muscles also develop *heat.* Living muscle has electricity in it; it is also always a little stretched, and that is why a wound gapes, for the sides of the cut muscle pull away from each other.

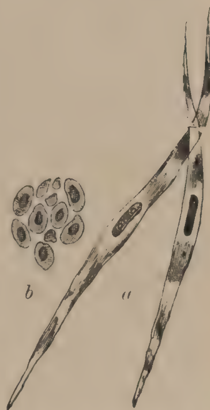


FIG. 26.—*a*, Smooth Muscular Fibres. *b*, Transverse section. Magnified.

How does each muscle gets its food and fresh air? The muscle citizens have a great work to do. They have to move the body about, and they have learnt how to do this so well that they have no time to prepare their own food, and they are cut off from the fresh air outside. The little one-celled animals in the water can get their fresh air from the water all round them, and they can catch and digest their food, but they have only feeble powers of movement. The muscle cells which have combined together have great powers, for they can move the bones at the joints and do work by contracting, and they have practically said to the rest of the body citizens, "We will do all your hard work; we will take you wherever you want to go; but, if we do all this business, you must arrange among yourselves to send us fresh air and food ready prepared, and you must send down messages to tell us

what to do, and as long as you keep us well we will always obey you." So a blood-vessel, called an artery, comes into every muscle from the left side of the heart. This artery is full of little red cells holding fresh air. It separates up into a regular network of tiny branches, and through the walls the fresh air and food get out to every cell, and the cells breathe out carbon dioxide gas and give out other waste matter which eventually gets back into the blood, and is carried to skin, and lungs, and kidneys to be got rid of. But sometimes the lungs and skin cannot do their work very well, because foolish people do not help them, and therefore the muscles suffer. How can we help our muscles to be firm, and strong, and to get plenty of fresh air and good food? One way is by *exercising* them. When we take plenty of exercise more blood comes to every cell, and the little cells get very active; they are able to build themselves up firm, and hard, and strong out of the extra air and food brought to them. Of course, the more work they are called upon to do, the more fresh air and food they need, and if they do not get enough they have to use themselves up, but as long as they can get enough the exercise is very good for them. If they do not get sufficient fresh air from the blood they soon get very tired, therefore it is important to take our exercise in the open air. We take our physical exercises in the open air whenever it is fine enough, because then the cells can get firm more easily and do their work better and also get rid more quickly of the waste matters. That is why also we should try to have doors and windows open if we are obliged to exercise indoors. It is much more tiring to take exercise in a stuffy town than it is to take double the amount in pure country air, or by the seaside, or on the hill. People who employ labour in factories find that their workpeople can get through far more work if they get plenty of fresh air, and they do not suffer from nearly so many illnesses. People who take no exercise are apt to get flabby, and pale, and unwholesome-looking, and their skins do not look clear. They are often people who eat quite as much as if the cells were needing a great deal of food, and, as they do not need so much, it does harm and very often upsets the digestion. People who have nothing the matter with them, but are too lazy to take exercise or do any work, are usually not the kind of people that England is proud of. We can think of many English heroes, who did great deeds and were strong men, and we like to think also that strong people are gentle and tender to those who are weaker and who cannot help themselves. Work and play are good for us all, but we ought to do our *own* work and our *own* play if we want to respect ourselves and have others respect us. Sometimes people get so into the habit of looking on at games that they never play themselves; they have forgotten that a love of games and sport should not be confined merely to looking at someone

else indulging in them—each man ought to take his own exercise, and each woman too. If people have to do work which does not give them proper exercise, then they ought to be very careful to get it in some other way, if they wish to keep well and strong. We hear people talking about *recreative exercise.* What does that mean? It really means exercise which does us so much good that it re-creates us—creates us over again. Swimming and rowing are splendid exercises, because they make use of nearly every muscle in the body. Walking, running, jumping, playing ball, and skipping are very good forms of exercise for growing boys and girls. Cricket and football are fine games, and when we play them ourselves, and do not merely look on, they do us a great deal of good. Bicycling has done people much good, but it is a pity if it makes them neglect walking. A good walk over the hills up into the pure high air is excellent for us and takes us where no bicycle can go. Climbing is very good, and exercises many muscles and makes us take the long, deep breaths which get quantities of fresh air into the lungs to make our blood rich and pure and bring health and strength to every cell in our bodies. Remember always that, if we do not exercise properly, poisons are apt to form in the liver and make us feel ill and melancholy.

If babies are fed on starchy foods when they are under six months old, their muscles usually get flabby. Milk gives babies good muscles, and they ought to have nothing else at that age. Starchy and sugary foods make children fat, but they do not make muscle. The foods which make muscle are meat, fish, milk, eggs, and cheese, also peas and beans, and whole-meal bread.

Now we will put on the blackboard some of the things we have learnt:—

1. Muscles lie over the bones and move them, and are bundles of fibres bound together.

2. There is red, striped, voluntary muscle outside, and white, non-striped, involuntary muscle inside the body.

3. Muscles need plenty of air and nourishment, which is brought to them by the blood, if people breathe pure air and eat proper food.

4. Do not let other people play your games for you; do your own work and your own play. You do not want a flabby mind and a flabby body.

5. Always exercise every day in the open air, if you want firm, healthy muscles, clear skins, and a cheerful mind.

6. Be a worker, not a shirker.

CHAPTER V.

THE HEART.

We have heard a good deal about food and fresh air coming to the cells of the body, but we have not yet heard how they are sent. Food and fresh air are prepared and obtained by some of the citizens, who then bring them to the heart, and it is the heart which sends them out over the whole body. It is as if the heart citizens had said: "We will distribute all the food and fresh air and undertake to see that you all get it, if you, on your part, will do the rest of the work." The heart is about the size of its owner's fist, doubled up. Where is it? On the left-hand side? I am afraid most people would say so, and think their hearts were in the right place too. People very often put their hands on that part of the food-tube which is called the stomach and imagine that their heart is there. Here is a diagram which shows you that the heart is in the chest or thorax and very nearly in the middle under the breastbone; but it curves over rather to the left, and its point beats against the chest wall, in the fifth rib space. Count on the diagram the spaces between the ribs and you will see (see fig. 37, p. 49). It is held up by big blood-vessels, and it rests on the floor of the chest, which is arched and is called the midriff or diaphragm. This floor is made partly of muscle and partly of tendon. The stomach is on the left, just under the diaphragm and close to the heart. If people overeat themselves, or have certain kinds of indigestion, it makes the stomach swell up and press on the heart, which is very uncomfortable sometimes, and often makes people think they have got heart trouble when they have nothing else but indigestion. The heart is really inside a double bag of membrane, which prevents it getting overstretched. What is the heart made of? Muscle. What kind of muscle? Is it red muscle or white muscle? It is red muscle. What did we learn about red muscle? That it is striped and under the control of the will. But the heart muscle is the great exception. It is red muscle, but it is not striped quite in the same way, and it is not under the control of the will. What are the heart citizen-cells like? Here is a diagram of heart cells. (fig. 29). They are square-shaped cells with a nucleus. Now the

heart, though a muscle, is really hollow, and it has been likened to a four-roomed cottage, but the two top rooms are so tiny we might call them attics. Notice the curious shape of these top rooms in the diagram of the outside of the heart (fig. 30). What do they look like? Rather like a little dog's ears. There is a Latin word which means a little ear, and these rooms are called *auricles* after that word. Do you notice anything else? Yes, a line runs across the heart. How does it run? Unevenly. Where is the point of the heart? On what side? On the right? No, it is on your right as you look at it, but it is really on the left side, just as it would be in a person who was facing you.

Here is a diagram of the heart, which shows the inside of the little four-roomed cottage (fig. 31).

It is a very curious house. Do you notice where the doors are? Only in the floors or ceilings. They are trap-doors and shut with flaps. On the right (your left) how many flaps are there? Three (tricuspid valve) (see fig. 32). How many on the left? Two (mitral valve) (see fig. 33). There are two big vessels bringing in the blood on the right side (fig. 32). Now these vessels bring the blood which has been visiting all the cell citizens. The top one (superior vena cava) brings the blood which has been giving fresh air and food to the head and arms. The lower vessel brings the blood from the rest of the body. This blood is dark purple, and it has little fresh air left in it; it is impure blood, too. Why? Because it has in it the poisonous carbon dioxide gas, which is part of the rubbish the

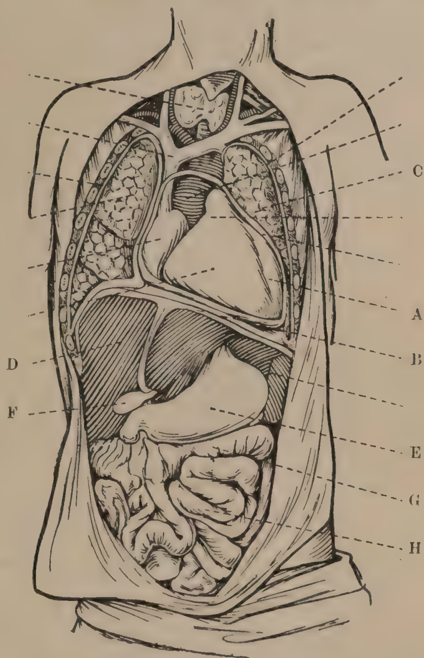


FIG. 27.—Dissection of the Body, showing position of the Main Organs.

A, heart resting on B, diaphragm. C, left lung drawn back. D, liver, drawn up to show E, the stomach. F, gall bladder. G, transverse colon. H, coils of small intestine.

cells have thrown away. Now we are going to see the way in which the heart citizens do their share of helping all the rest of the body. When the blood comes in to the right top room it finds the trap-door open, so it rushes down and begins to fill up the ventricle, as the lower room is called. But the auricle is so tiny that it gets full before this happens. Now, of course, directly the auricle is full the walls of it feel the pressure on them. The walls, as we remember, are made of cells, and they, being muscle cells, answer to the pressure (*i.e.* respond to the stimulus) by contracting and so getting shorter and thicker. Can you understand what must happen? Yes, the whole auricle squeezes up tight. That is to say, the heart gives a beat. Now where does the blood go to? It is like people in a crowd being crushed, is it not? They cannot get out as they came in, because the two roads (superior and inferior venæ cavæ) are full of people waiting to come in also, so they run through the trap-door and fill up the rest of the lower room, which we call the ventricle. Now the same thing happens. The walls feel the pressure on them, and all the active heart citizens reply by contracting, for that is what all muscle has promised to do when a stimulus comes to it. So the ventricle squeezes itself together and the heart gives another beat. Now where are the citizens in the blood going? Back through the trap-door? No. For the little flaps have floated up and the door is tightly shut. If the blood pushes hard do you think the doors can be opened the wrong way? No. For these flaps are fastened by very strong, fine cords to the walls of the ventricle, and the cords will not stretch at all. The doors are fast shut. So the citizens have to go up the chimney. Yes. There is a big blood-vessel which opens out of the top of the ventricle, and the blood passes up it. Here it is on the diagram (fig. 31, C). It is called the lung artery (pulmonary artery), because it carries the blood to the lung and *from* the heart. All vessels going to the heart are called veins, all vessels coming from the heart are called arteries. This is the only artery which carries blue (venous) blood. When it gets to the lung the artery divides up and the branches become so fine that they can only be seen through a microscope (fig. 34). Blood-vessels as tiny as these

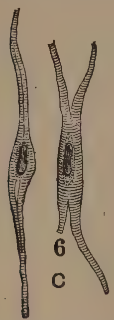


FIG. 28.—Muscular Fibres from Heart of Frog.

FIG. 29.—Muscular Fibres from Heart of Mammal.

are called *capillaries*; they have very thin walls, and through the walls the harmful carbon dioxide gas passes *out* and presently finds its way into the air through the nose and mouth. Through the walls, however, the life-giving gas, oxygen, passes *in*, and then the citizens in the blood seize hold of it and a wonderful change comes over them: they were

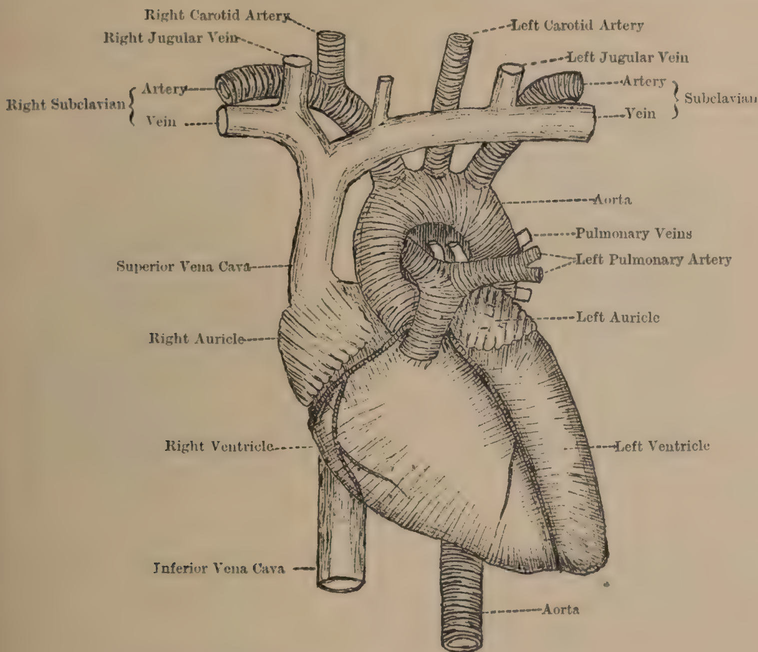


FIG. 30.—Diagram of Heart, showing position of Auricles.

purple in colour before, but now that they are loaded up with their burden of fresh air they turn a most beautiful scarlet. They rush away to the left side of the heart, quickly carrying the fresh air to all the cell citizens who are waiting and crying out for it, from the cell citizens forming the skin and hair on the crowns of our heads to the citizens who form the skin on the soles of our feet. The fine capillaries become larger and larger, until they form four veins called lung veins (pulmonary veins), and open into this little top room on the left side of the heart (fig. 33 *g*, *g*). What is it called? The left auricle. Then the

same thing happens as on the right side. The auricle gets full before the ventricle does, and it forces the blood into the latter, which also contracts. The two tough flaps of the mitral valve float up and close the way, and therefore the cell citizens, carrying their burden of fresh air, have to rush up a kind of chimney in the top of the ventricle. This is a big blood-vessel, called the *aorta*. It is an artery, because it carries

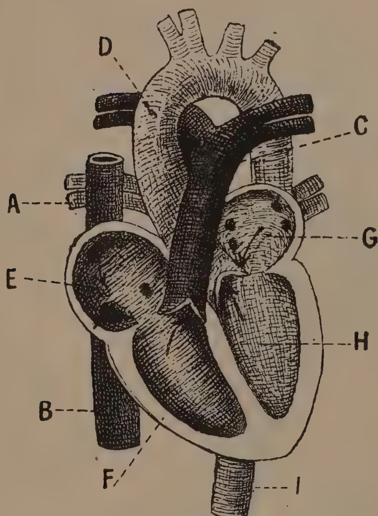


FIG. 31.—Section through Heart.

A, superior vena cava. B, inferior vena cava. C, pulmonary artery. D, aorta. E, right auricle. F, right ventricle. G, left auricle. H, left ventricle. I, descending portion of aorta.

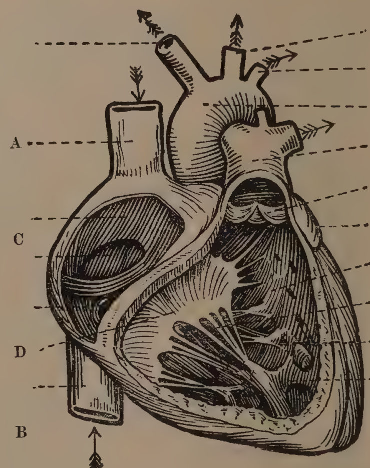


FIG. 32.—Dissection of right side of the Heart, with arrows, showing direction of flow of blood.

A, upper hollow vein (superior vena cava). B, lower hollow vein (inferior vena cava). C, right auricle. D, tricuspid valve.

blood *away* from the heart. Both the aorta and the pulmonary artery have soft but strong valves or pockets of fine membrane on their walls just where they leave the heart (semi-lunar valves), and no blood can get back the wrong way, because, if it tried to, it would get into the pockets and bulge them out so much that they would meet in the middle and fill up the whole space. The heart is thus like a pump, and sends the blood along vessels all over the body. In another lesson we shall see how the aorta divides up and how the blood is distributed.

But how does the heart get its own food and fresh air? How does it get its own rubbish cleared away? Just as the blood enters the

aorta two tiny branches open close behind two of the valves. These are the heart arteries (coronary arteries). They run to both sides and give off branches. Through the walls of the branches the fresh air and food get to the cells, and then the impure air (carbon dioxide) and other rubbish get into the branches, which by degrees become veins and open into the upper big vein on the right-hand side, in order that

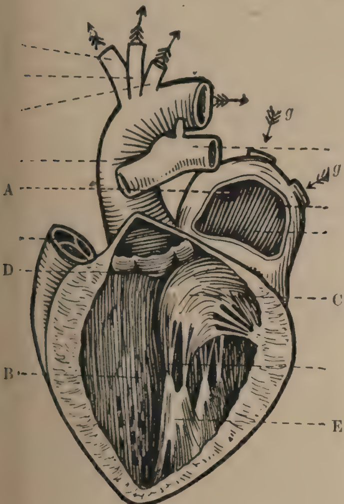


FIG. 33.

A, left auricle cut open. B, left ventricle. C, mitral valve. D, semi-lunar valves at base of aorta. E, papillary muscles. *g, g*, two pulmonary veins opening into left auricle. Arrows denote direction of blood flow.

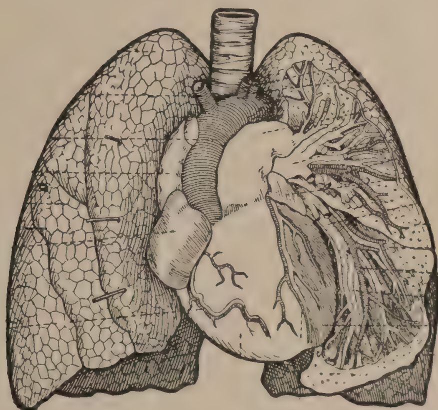


FIG. 34.—Left lung drawn away from Heart and partly dissected, showing the branching of the blood-vessels going from and to the Heart.

the blood may be sent at once to the lungs to be purified and to get more fresh air.

How important it must be to see that the heart, which has to do all the pumping work, should get fresh air and good food! If we eat wrong kinds of food and if we breathe bad air, the heart citizens get weakened. They get weakened, too, if we allow poisons to get into the blood, as people do who are not particular to get rid of waste matter every day, or who have dirty skins and so do not allow the skin to do its share of purifying. Some things also are specially dangerous when the heart cells are young; one of these is cigarette-smoking. Boys who smoke cigarettes are apt to get weak hearts—that is one reason

why the law will not allow it. It is very silly to make our hearts weak. Cigarette-smoking, too, when it is done by growing boys, poisons the other cells, and the body does not grow properly. Grown-up people are sometimes foolish enough to smoke too much, and both that and drinking too much wine, beer, or spirits is very apt to injure the heart seriously. Bicycling up very heavy hills is a strain on the heart. The heart beats naturally about seventy times a minute, and rests a little between each beat. If we do things that are too hard for us—foolish things—the heart cannot rest properly or get proper nourishment. But exercise is very good for it, for it strengthens it, just as it strengthens all the other muscles. Exercise quickens the heart's beat, brings in more fresh air, clears away rubbish, and helps the heart to send the food and fresh air all round the body. It also prevents chilblains, because it improves the circulation. People who take no exercise are apt to have rather flabby hearts.

Now we will put on the blackboard some of the things we have learnt:—

1. The heart is a pump which sends food and fresh air in the blood all round the body.

2. It is a hollow muscle, containing four chambers.

3. The impure blood comes in from the body on the right side of the heart. It is purple in colour, and the right ventricle pumps it into the lungs to be purified.

4. Blood which contains fresh air is scarlet in colour, and comes into the left side of the heart from the lungs, and the left ventricle pumps it into the aorta and sends it all round the body.

5. People who want healthy hearts and good circulations should breathe pure air and take plenty of exercise. They should also get rid of rubbish every day and keep their skins clean and active.

6. Boys and girls should never touch drink or cigarettes; both injure the growing heart.

CHAPTER VI.

DISSECTION OF A SHEEP'S HEART.

Necessary Apparatus.

- A sheep's heart.
- A board on which to dissect it.
- A smooth-ended glass rod.
- A jug of water.
- A small funnel.
- Small, sharp scissors.
- Sharp scalpel or razor.

THIS is a sheep's heart, and I have placed it with the point towards you. Which is the right side and which is the left? You must remember that you are looking at it as if it were in the animal's body, so its right side is on your left, just as a person's right hand is opposite your left hand when you stand in front of him. Notice the line which goes across the heart from the top to the bottom, slanting to its right. This divides it into the right and left sides. The front of the heart is rounder than the back, which is rather flat; but even if it were not so, we could still easily find which was the front because of the difference in feeling between the right and left sides. If I press this right side with my finger it feels soft, but if I press the left side it feels much firmer. What does that show? It shows that the left side must be stronger than the right. Why is that? What has the right side of the heart to do? It has to pump the blood into the lungs to get fresh air. That is not very far to have to send it, so it need not be so very strong. But where has the left side of the heart to pump the blood? All round the body! Up to the top of our heads and right down to our toes. So it has to be very strong and have good thick muscular walls. In this groove which runs down across the heart there is fat, and there is another shallower groove at the back. Now look at the top of the heart. What are these things which stick out on each side? Rather like ears. What are they? They are part of the two top rooms in the heart; the rooms which we call auricles. Now the blood comes to the right side through two veins. Let us see if we can find the top one. Veins have such thin walls that this vein will be quite collapsed and its sides will be sticking together, so it is not easy to find it at first, especially as probably it has been cut off very

close.[1] Here is something which looks like it, you might almost mistake it for a piece of thin skin. I am passing this glass rod down it. See how wide it is and how thin and soft! Now the rod's point is inside the auricle, and if I push it on I ought to push it into the opening of the lower big vein. Yes, here it is coming out of the auricle by the lower opening. So now we have seen both veins, and we will cut along the veins and the auricle as they lie over the rod, and so open up the little upper chamber. It is very small, as you see. Notice the thin walls, and how they are strengthened inside by little columns and bands of muscle (columnæ carnæ) which have a very curious appearance. Now we will clear away some of the fat round the big vessels at the *base* of the heart, as the upper part is called. Here is a big blood-vessel which is wide open and has strong elastic walls. Arteries always stay open because their walls are so strong. Let us see which artery this is. We will put this glass rod down, and if we find that the end goes into the right ventricle, we know that this must be the pulmonary artery. Now we will cut it open close to where it starts out of the ventricle and look inside. What do you see? Three little flaps, as if watch-pockets had been sewn on to the side. These are the semi-lunar valves. I will pour a little water in. What has happened? The valves have got full of water and closed together and the water cannot pass them and get down into the ventricle. We remember that the only way *into* the ventricle is through the trap-door in the floor of the auricle. Let us look again at the auricle and open it now very widely. What do you see? Three curious white triangular flaps hanging round an opening into the ventricle. We can push the glass rod right down this trap-door into the ventricle. Our best way to see the valves act will be, not to pour water in this way, but to put a funnel down the pulmonary artery so that we press the semi-lunar valves back against the wall and get the end of the funnel into the ventricle. Now I will pour water down it while you look into the auricle and watch the trap-door. What is happening? The valves have floated up, the door is tightly shut and no water is coming out. Now I will take the funnel out and press the right side of the heart, to imitate what happens when the ventricle contracts as soon as it is full. What happens? Does the water come into the auricle? No, it comes out of the pulmonary artery, and that is the artery which leads to the lung.

Now we will go to the other side of the heart and cut through the aorta close to the left ventricle and look in. What can you see when I pour water in? Three semi-lunar valves closing up just as the others

[1] These veins are often cut off so closely by the butcher that part of the auricle is also cut away and their presence cannot be demonstrated. Care should be taken to warn the butcher about this.

did at the root of the lung artery on the right side. What do they do? They prevent the blood from running back into the heart after the heart has sent it into the aorta. We will now find the veins which open into the left auricle. Where do they come from? From the lung. What colour is the blood they bring? Scarlet. There are four in man, but only two in a sheep. Now we will cut open the auricle and look at it, and we shall see the trap-door or valve, as we call it, which leads into the left ventricle. We will put the funnel into the ventricle through the aorta and fill the ventricle with water. What happens? The flaps float up and the trap-door closes. How many flaps are there? Two. This valve is called the mitral valve because it is supposed to be shaped like a bishop's mitre.

Now we must open both ventricles. We will do this carefully by cutting on both sides along the groove, about half an inch away from it, and then cutting along the side of the heart from the point or *apex*, as it is called, towards the base. Now what do we notice about the walls? Are they the same thickness? No. The left side has tremendously thick walls, as it has to pump the blood so far (compare also figs. 32 and 33). Notice how thin and clear and almost transparent the valves are as I run my finger under one of them. But they are very tough and strong. Notice the fine, white, glistening cords attached to their edges and on to the sides of the heart. These cords are the heart-strings (chordæ tendineæ). They are tendinous cords which will not stretch and are just long enough to allow the trap-doors to shut tightly, but they will not allow them to be pressed open the wrong way, for they pull them back at once. They are fastened on to the sides of the heart on the top of little hills of muscle (papillary muscles). Notice the curious bands of muscle which strengthen the heart walls in various directions. Some cross from side to side to prevent the heart from stretching too much. Notice also the smooth shiny lining of the inside of the heart (endocardium). Now you can see the openings of the lung artery and of the aorta. We will open the aorta and look at the watch-pocket valves, and behind two of them we see tiny openings. These are the little branches which carry food and fresh air into the walls of the heart itself to nourish the cell citizens.

Now we will sum up what we have learnt:—

The impure blood from all round the body comes into the right auricle, and begins at once to run through the tricuspid valve into the ventricle, which it partly fills. By this time the little auricle is quite full, in spite of the trap-door being still open; the walls contract and the auricle is emptied into the ventricle, which was partly full before and is quite full now. The valves then float up and close the trap-door and the walls contract and pump the blood away. It cannot

break the trap-door open the wrong way, because the fine cords attached to it will not stretch any more, so the blood is forced up the lung artery, which is the only other opening. The blood cannot run back into the heart on account of the semi-lunar valves at the bottom of the artery. The blood is purple when it comes to the lungs, but in the lungs it gives up carbon dioxide and takes in fresh air and becomes scarlet. It comes back to the heart on the left side, carrying its fresh air, and four veins bring it to the left auricle. It is then sent through the mitral valve into the left ventricle, and the left ventricle pumps it into the aorta, a big, strong artery, and sends it all round the body, to return in time in veins to the right side of the heart.

CHAPTER VII.

WHAT BLOOD IS AND WHAT IT HAS TO DO.

Necessary Apparatus.

A bottle containing water and cranberries. An unripe cranberry should be put in for about every 500 ripe ones.
Drawing of red and white cells on the blackboard.
Glass of hot water.
Rod or spoon, as stirrer.
A lump of sugar.

Suggested Additional Apparatus.

A microscope.
Clean needle.
Piece of fine string.
Glass slide.
Cover glasses.

Wind the piece of string firmly round the top of a finger and allow the veins to become full of blood brought by the deeply buried arteries. Prick the finger close to the nail. Smear the blood on the slide and spread it out *very thin*. Cover with cover glass and examine. If a little tap or pressure be made on the cover glass, the plasma will be set in motion and the corpuscles will be seen streaming along in it.

Here is a bottle full up to the top. What colour do you see? Red. Is it full of something red? Look closer. No, it is full of water, in which are a quantity of little red berries, and every now and then a white berry. These are cranberries. Is blood red? Yes. Well, it certainly looks red to us, but if you looked at it under the microscope you would see that it was pale straw colour, rather like water, and that floating in it were lots of little red cells (corpuscles) and now and again a larger white one. Do you remember about the red marrow in bones? That is where the red blood-cells begin their life. They are really not quite true cells, as they have no nucleus but are formed by breaking off from big real cells. There are millions and millions of them, and they are so tiny ($\frac{1}{3200}$ of an inch) that there are about five million of them in a drop of blood the size of a pin's head. There are about 500 red cells to every white one, and the white ones are a little bigger ($\frac{1}{2500}$ of an inch). These red cells do a wonderful work, as we already know, for they say to the other citizens of the body: "We will spend our lives in carrying fresh air for you, if you will undertake to send us

where we can get it and to carry us round afterwards." "Yes," say the lung citizens, "we will undertake to get the air and to make tubes for it to flow in, but how will *you* get to us?" "Never mind that," say some other citizens; "we will undertake to form tubes called blood-vessels for the fresh-air carriers to run in, if only the heart citizens will allow the tubes to start from their place and will undertake to send the cells along, for they cannot go far without a good push off." "Yes," say the heart citizens, "we will do that gladly." "All right," say some of the governing cells in the brain and nerves; "we will see that everybody does his duty; but we want a lot of fresh air ourselves, please, if we have

FIG. 35.—Red and White Cells.

A, 1, red blood-corpuscle on the flat; 2, on the side; 3, unchanged blood-plates; 4, lymph-corpuscle and blood-plates.

B, human leucocytes, showing amœboid movement.

to look after everybody else, and if you do not let us have plenty all will suffer. Therefore we very much hope that whoever may own us will be wise enough to see that we all have a chance of getting plenty of fresh air, for none of us can do our duty properly unless our owner does it too."

Here is a picture of the red and white cells, showing how they look under the microscope (fig. 35.) And fig. 36 shows us how curiously the red cells run together while we look at them under the microscope and form little piles like pennies on top of each other. The main business, then, of the red cells is to carry fresh air. The white cells are true cells, with a nucleus. They are very like the little one-celled creature we heard about in our first lesson—the one called an amœba. If we look at one under the microscope and keep it warm, we can see it

wandering about. These white cells (leucocytes) are a great help to us. They can make themselves very thin and so can push their way in between the cells which build up the walls of the very tiny blood-vessels, where the walls are only one cell thick. They squeeze through and wander about and pick up rubbish and carry it away, for fear it should harm the rest of the body. They are called "wander cells," and "scavenger cells," and "eating cells" also (phagocytes), because they eat up harmful germs if they get into the blood. Here is another picture of them (fig. 36A).

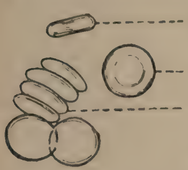


FIG. 36.—Red corpuscles forming into piles.

But blood is also watery, as well as having solid cells in it. Is there anything in the water? Here is a glass of hot water. I will drop this lump of sugar in and stir it round. Now the sugar has melted. Can you see it any longer? No, it has quite disappeared. Has it gone away? No, it has really filled up spaces between the particles of water and displaced air. If we tasted it, we should soon find out that it had not really gone. It has dissolved, or, as one ought to say, *it has passed into solution.* Now the wonderful thing is that the watery part of the blood (or *plasma*, as it is called) is full of food in solution. It holds dissolved salts, and dissolved sugar, and also starchy foods, and meaty foods, which have been digested until they melt as easily as sugar does; it holds lime salts for the bones; in fact, it holds all the different kinds of food that the cell citizens require.

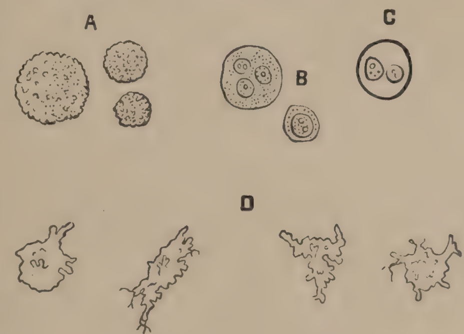


FIG. 36A.—Leucocytes.

A, human white blood-corpuscles, without any reagent. B, after the action of water. C, after acetic acid. D, frog's corpuscles; change of shape due to amœboid movement.

It is very important to eat proper food. Sometimes people will persist in giving babies food which they cannot digest properly, and this food never gets into the blood, therefore the poor baby is really starved, for much of the food taken is really worse than useless. Starchy food for babies under six months old cannot be properly digested, and even if some babies manage to digest a little, it does not make firm muscle—

it makes fat only. This liquid part of the blood can soak through the walls of the thinnest and finest of the blood-vessels and so feed the cells in the particular part through which the vessel is running, which may be muscle, nerve, membrane, or any other kind of tissue. It is called *lymph* when it oozes out among the cells. The red-blood cells cannot get out into the lymph unless the blood-vessel is injured, but the white ones can. When the lymph has come close to the cells and the cells have taken their food out of it, it flows back into the blood, but usually not at once; it passes into other vessels called lymphatics, which join the blood-vessels later on. Every now and then the lymphatics widen out and become comparatively large and spongy. These larger parts are lymphatic glands, and in them the lymph is filtered, and if any harmful thing has got in, as it may do through a broken skin, the gland tries to keep it and prevent it from getting into the blood, where it would do harm. Big white cells grow in the walls of these glands, and if the white blood-cells have brought in germs which have got in through a wound, and have not yet eaten them and so destroyed them, then the big cells try to do so. If we cut our finger, we ought to be careful when we bind it up not to put anything dirty on it, because dirt means germs, and germs are very tiny little plants, which do much good in their proper place, but much harm out of it, and they ought not to be under our skins or get into our blood. Directly they get in, up rush the white cells and try to kill them. If they succeed, the wound soon heals. Sometimes the white cells get killed by the germs, and then matter forms in the wound, and that is made up partly of the dead bodies of the white cells which have been fighting like brave soldiers to defend their country. Sometimes, if we poison a cut finger, we can see a sort of network of red up the back of our hands. These are the inflamed lymphatics carrying off the poison to glands in the elbow to be destroyed. If the cells in the glands have much poison to deal with, the glands may ache and inflame, and perhaps the poison escapes and goes up to the armpit, where it will have to pass through many glands, and usually gets destroyed; and therefore, when the lymph comes out of the glands, it is quite pure again and is poured safely into the veins near the neck, and then goes across in the superior vena cava to the right side of the heart. It is wonderful what care the active white soldier-cells take to keep out enemies, but it shows us how silly it is to put dirty things like cobwebs on a cut. By using such things, we may easily make ourselves very ill indeed, for the germs may enter in such quantities that the cells and glands cannot stop them, and they get into the blood and give us fever and pain.

But there is one more thing I want to tell you. In the watery part of blood is a substance which gives rise to what is called *fibrin*. Fine

white strings form whenever blood is exposed in a cut, and these strings form a network, which entangles the red and white cells and makes what we call a clot. Blood-plasma, without fibrin, is called *serum*. This power of blood to clot when it is exposed to air is very valuable, for it stops the bleeding from wounds. Blood will also clot if it touches something which is not naturally in it, and soft fluffy things make it clot quickly, for clots form on all the threads or hairs. Soft lint or clean cotton-wool will help blood to clot and are safe things to use, whereas cobwebs are very dangerous. It is dangerous also to put earth on a wound to stop its bleeding, as field-labourers sometimes do, for germs which can cause lockjaw are found in manured soil.

When blood is sent round the body and has collected rubbish, it carries some of it to the kidneys, which have to take out a certain kind of salt, called urea; it also goes to the skin, where it gets rid of a little carbon dioxide, some common salt, and also a little of another impurity (urea); in the lungs it gets rid of carbon dioxide; while in the kidneys, skin, and lungs it also gets rid of water. So these three organs have agreed to get rid of body refuse, if their owner will keep them in working order. We need to see that our lungs get plenty of fresh air, and that we wash the impurities and dirt off our skins, remembering also that, if the skin does not do all its work, the lungs and kidneys will have to do more than is good for them. Fresh air, cleanliness, and good food are what make the blood able to work well and get rid of rubbish; exercise sends the blood quicker round the body and helps it, and being careful to get rid of all body refuse every day prevents harmful things from getting back into it.

We will now put on the blackboard some of the things which we have learnt:—

1. Blood is made up of a liquid part called plasma, and of solid cells called red and white corpuscles.

2. Red cells are the fresh-air carriers of the body, and white cells are the soldiers who keep out enemies. Plasma contains food matters for the use of the body cells.

3. Blood has the power of clotting. When it clots, a white stringy stuff called fibrin is formed out of the plasma. This entangles the red and white cells and forms the clot.

4. Blood without fibrin and cells is called serum.

5. Blood carries the rubbish to the lungs, kidneys, and skin to be got rid of.

6. Fresh air, clean skins, good food, and plenty of exercise make good blood.

CHAPTER VIII.

THE CIRCULATION OF THE BLOOD.

Necessary Apparatus.

A small piece of rubber tissue.

Wall diagram or blackboard drawing oi arteries passing into capillaries and veins.

Piece of fine string.

Note.—If possible, the children should always be made to perform the small experiments given in the text.

We have already learnt a good deal about the movement of blood in the body, and that the right side of the heart receives it and sends it through the lung artery into the lungs, whence it passes to the left side of the heart, to be sent round the body and back to the right side. We do not know quite all about it, however. For a long time no one knew that blood was going round the body at all, but a great Englishman, called Harvey, felt sure of it, and he made several experiments. He said that blood left the left side of the heart in vessels called arteries, and came back to the right side in vessels called veins. But people said: "That is all very well, but how does it get from the arteries into the veins, because we find arteries come to an end and we find veins beginning?" He said that there must be tubes between the two, and he proved it by experiments. After he was dead, the microscope was very much improved, and then for the first time it was actually *seen* that Harvey was quite right: little passages existed, but so fine, far finer than the finest hairs, that they cannot be seen by the naked eye. These little tubes are joined all in one to the arteries and the veins, and are called capillaries, from a Latin word meaning a hair, because they are so fine.

Arteries are vessels which carry blood *from* the heart; they have very strong walls, as you have seen, and are always found open. The walls are made in at least three layers, called coats. The outer coats have elastic fibres and unstriped muscle fibres in them, and the inner coat is made up of cells joined edge to edge, and is very thin and smooth. Big arteries are very elastic and can stretch a great deal,

just as this piece of indiarubber tissue stretches when I pull it, and falls back again when the force is taken away. When the heart

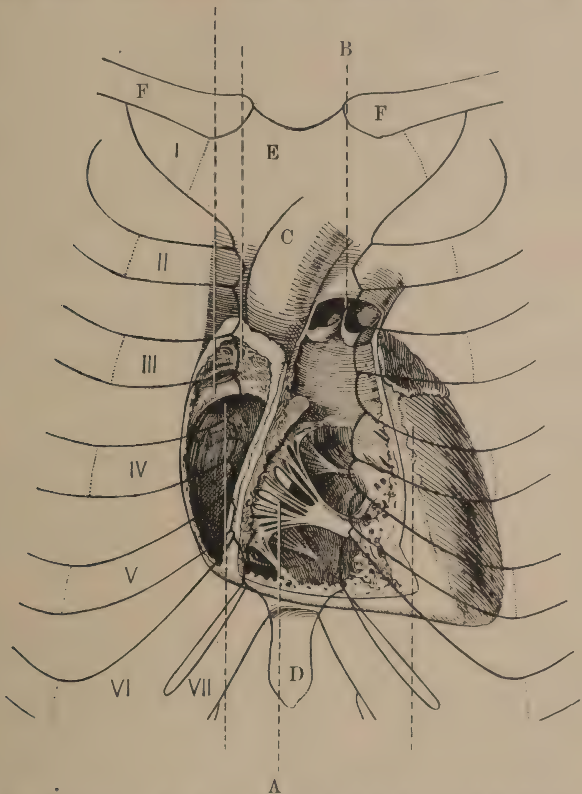


FIG. 37.—Position of the heart in the chest with regard to the ribs and breast-bone. The right side is dissected and shows the interior of the right auricle and ventricle.

A, tricuspid valve. B, semi-lunar valves at base of lung artery. C, aorta. D, Point of the breast-bone which is here shown as if transparent. E, upper portion of breast-bone. F, Collar-bones. Roman figures refer to the ribs, also shown as if transparent.

pumps blood into a big elastic artery, each beat pushes out the elastic walls, and in between the pumping (when of course the blood in the artery is not being pressed upon by more blood coming in) the elastic

walls fall back and press the blood onward, and so help the heart very much. We can feel this wave of blood if we put our finger on an artery. Nature always tries to put arteries in very safe places, where they cannot get hurt, but sometimes they come near the surface on the inside of a limb, where they are usually pretty safe. Wherever an artery comes near the surface we can feel what is called a pulsation or *pulse.* A very convenient one to feel is the radial artery in the wrist, which is usually called *the* pulse, just as if there were no other pulses. Put your finger on your cheek quite close to the middle of your ear where a tiny flap pushes out over the ear opening. What do you feel? You feel something throbbing: that is a wave in a small artery; it is a pulse, and beats every time the heart beats; it is the wave pushing against the wall as the heart pumps the blood on. Inside are the bright red-blood cells hurrying along. What are they doing? Carrying fresh air up to your head. Put your fingers on the inner side of the top of your thumb. Do you feel another pulse? Press your fingers on the sides of your throat. What do you feel? A big throb. That is a big artery carrying food and fresh air to help you to think and work, and it nourishes your hair, and gives you a colour, and does many other things for you.

Veins are thin-walled vessels which carry blood *to* the heart. They are found closed after an animal is dead. We cannot feel a pulse in them, for the wave dies out before it gets to them and the blood is moving very quietly now, though it dashes along quickly enough in the arteries. Veins are often found lying close under the skin, and look blue.

Capillaries are the very fine parts running between arteries and veins. There is no division. A small artery becomes several capillaries, and several capillaries become a small vein. The capillaries have only one coat, and it is very thin. All the nourishment and fresh air brought by the blood have to get out through the thin walls. Here (fig. 38) is a diagram of how arteries and capillaries and veins join together. You may imagine that this is the tip of your finger or any other part of your body where blood-vessels go.

It is the presence of blood in the capillaries which makes skin look pink. Press your finger-tip very hard on the desk in front of you. What happens? It goes white. Why is that? Because you are pressing the blood out of the capillaries. Let your hand hang down by your side. Now look at it quickly. What do the veins look like? They look large and swollen. Now lift your hand above your head. What do you notice? The hand gets whiter and the veins get small. Why is it so? Because it is much easier for the blood to run downhill than to run up. Blood in the veins very often has to run uphill before

it can get back to the heart—from the arms and legs, for instance. How does it manage to do it? It does it partly because the heart acts like a suction-pump, and partly because it can only move in one direction for any distance, because of little watch-pocket valves which lie smoothly against the sides whenever the blood is going properly towards the heart, but directly the blood goes too slowly, or is stopped and tries to run backwards, then it gets into the watch-pockets and swells them out so that the whole passage is stopped. Stroke one of your veins in a direction away from the heart. What happens? It gets full and blue and swells out at one place. That is where a valve is. If we tie tight things round our limbs, we often press on the veins,

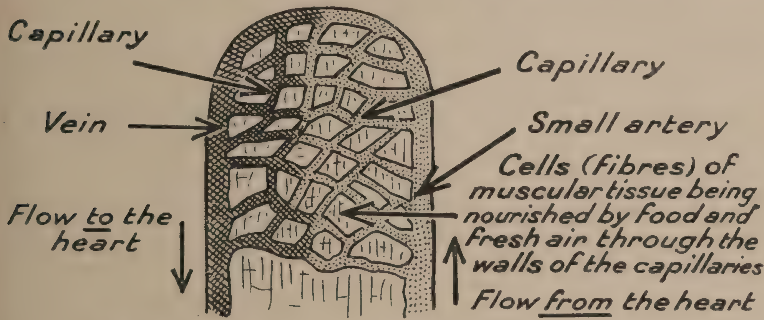


FIG. 38.—Diagrammatic representation of network of Capillaries.

and then the blood cannot travel on properly, and the watch-pocket valves swell out so as to prevent it running right back, and perhaps the walls are stretched very much by the pressure, and then people get what are called varicose veins. When people stand a great deal they are apt to get these swollen veins, for they do not get enough exercise. Exercise makes the muscles contract and press on the veins and help the blood on, but standing or sitting too much makes the circulation very slow. Sometimes people who have stood too long get very faint, because the blood collects too much in the big lower veins, and there is too little left in the brain. When that happens, we lay them down flat with their heads low, so that the blood can run towards the heart and be sent to the head. Not getting rid of rubbish every day is bad for veins, for sometimes the lower part of the food-tube gets full of waste matter and presses on the veins, causing varicose veins, especially in the left leg, which is nearest to the food-tube. Poisons also will pass from the waste food in the food-tube when the former has not been got rid of,

and will get into the blood and weaken the walls of the blood-vessels. People who drink too much alcohol are very apt to injure the blood-vessels. These get irritated with the drink in the blood, and very often become hard and brittle, and the whole body suffers then, for the arteries are no longer elastic and cannot help to make the blood circulate. It also means more work for the heart, which often becomes weakened by overwork and poisoning. It is a great pity to injure ourselves in this way, for we can never be well if our arteries are hardened.

One reason why we make you do physical exercises after you have been taking a lesson, sitting at your desks, is that the moving muscles may press the blood on. Proper exercise freshens us up wonderfully, sends the blood coursing round the body, warms us up, sends blood to our brain, and helps us to do the next lesson better. There is nothing like exercise for improving the circulation of the blood, which brings fresh air and food to all the body, clears away the rubbish, and makes us feel and look well. Now we will perform a little experiment to prove to you that blood goes round the body. I will tie this piece of string very tightly round the tip of my middle finger. What has happened? The finger tip is turning quite dark red and even purple. Why? How is the blood coming to the finger-tip? By a little artery from the heart. Is the artery on the top near the skin, or is it deeply buried? It is deeply buried. Nature usually buries the artery deep. So when I bind the string tightly round I am not binding it hard enough to stop the blood coming in the artery, and the finger goes on getting blood. But what about the veins? Where are they? Near the top and very soft, so that it is easy to press on them. What is the string doing? It is preventing the blood running away up to the heart in the veins, and as the artery is not stopped the finger is getting more and more full of blood and would get painfully swollen in time. Now I will take off the string. What happens? The blood runs away at once and the finger regains its natural colour. What does this experiment show us? It shows us that blood is going round and round the body and that we can stop it by pressure. If we cut our fingers badly, we must remember that holding our hand up helps to stop the bleeding, for then the blood in the artery has to run uphill. If any dirt has got into the wound, we must wash it gently away with a clean rag and a little warm water; and if the bleeding continues we can let cold water run over it and bind it up firmly with soft, clean rags, for then the blood will soon clot and stop the bleeding. We can stop any blood going down the arm if we put a hard pad on the top of the artery in the upper arm and bind a handkerchief round, and then put a stick in and twist it tightly. That presses the hard pad against the artery which lies on the inner side of our arms,

just under the seam of our coat-sleeves, and it also presses the artery against the bone of the arm. We can also catch hold of the arm with our hands and press our fingers on the artery, and the artery against the bone, and then a cut would soon stop bleeding, for no more blood could come to it. That is a very good thing to do if an artery is wounded, and we ought to do it very quickly. We know directly when it is an artery, for the blood is scarlet and comes out in jerks. When a vein is wounded the blood is dark and wells out slowly; when we cut our fingers it is usually only the little capillaries that are hurt, and the blood merely oozes out and is very easily stopped. We must always cover up the wound, even if we have stopped the artery higher up. Never use stamp-paper for a cut, for there may be germs in the gum. Always use clean things. If a wound gapes, then we must sometimes pull it together with little strips of sticking-plaster. When we want to put a clean dressing on a wound we ought not to pull the old one off roughly, but if it sticks we ought to soften it with clean warm water, using a clean rag or clean cotton-wool, which is much better than using a sponge, which perhaps has got soap and evil germs in it.

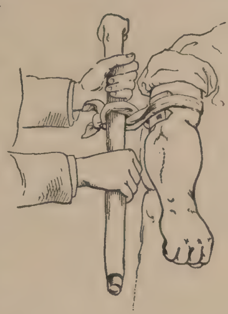


FIG. 39.—Handkerchief-and-Stick Tourniquet.

Now I will put on the blackboard some of the things we have learnt:—

1. Blood-vessels consist of arteries, capillaries, and veins.

2. Arteries have thick walls and bring pure blood to every part of the body from the left side of the heart, and gradually become capillaries.

3. Food and fresh air pass through the capillaries to nourish the body cells, and the capillaries gradually become veins, carrying impure blood to the right side of the heart to be sent through the lungs and purified and return to the left side once more.

4. A pulse is a wave of blood passing through an artery, and is felt at every beat of the heart.

5. Strong drink, constipation, and want of exercise injure the heart and blood-vessels.

6. Exercise and deep breathing improve the circulation, help to bring food and fresh air to the body cells, and clear away the rubbish.

CHAPTER IX.

THE AIR WE BREATHE.

Necessary Apparatus. (For full instructions see text.)

A large, deep trough of water (glass, if possible).
Two or three small test-tubes and one large one, for the experiment with the rubber tissue.
Magnet and needle.
A lump of sugar. A lump of *dry* earth.
Two small tumblers or beakers.
A small piece of thin cardboard.
A glass flask.
Spirit-lamp or Bunsen burner.
Tripod.
Wire gauze, or a sand tray, to put under the flask while heating the water.
A tin cup.
A little ice or very cold water.
A piece of rubber tissue. The best kind to use is thin rubber, such as is used by dentists. This rubber must be absolutely free from "pinholes" or the experiment will be a failure.
A paper spiral and pin.
A medicine-bottle fitted with a tight-fitting cork, preferably rubber. Through the cork passes a glass tube.

Accessory Apparatus, to be used if desired.

Balance for weighing flask of air.
Flask for air.
Air-pump.
Small vessel for mercury.
Glass tubing for making a thermometer.

Note.—Other experiments and variations of the experiments suggested can be introduced by the teacher, if desired. For list of suggested text-books, whence such can be taken, see Appendix.

It is of the utmost importance that the teacher should have tried the experiments beforehand, and have ascertained that he can do them. All apparatus needed should be ready to hand. The pupils should always be questioned as to what can be observed, and should be taught to notice everything for themselves. *This is essential.*

We are going to talk about air to-day, because it forms an important part of our talks on health. There are some people who say that you ought only to believe what you can see, but we cannot see air,

and yet it is so important to us, that if air were taken away we should die in a few seconds. But we can *feel* air. Move your hand and arm quickly backwards and forwards and you will feel a draught. Outside when the wind is high we can feel the air very strongly. It goes all round the earth, like a covering, and would fly right away from it, if it were not that the earth is like a great magnet and keeps pulling it back. (Here the teacher should draw a globe on the blackboard, and add a narrow blue border all round to represent the atmosphere. It will be proportionately far too large, however narrow it is drawn; this can easily be explained.) Probably air comes to an end about a hundred miles away from the earth, and beyond it there is only what scientific men call *ether* until, if you could go there, you reached one of the planets that shine at night; they have coverings of air round them, just as the earth has. The moon has no air covering, so we know that no human beings can live on the moon. We call the air coverings the *atmosphere.*

Do you see this test-tube? Most people would tell you that it was quite empty, would they not? Let us see if they are right. Here is a big glass vessel full of water. As it is glass you can see through the sides. I have filled it with water into which I have put a little drop of Condy's fluid, so that you can see easily what happens. Now if this test-tube is really empty, then, as I press it *straight down* into the water, the pink water ought to come inside it, as there is nothing else in to keep the water out. See! I am pressing it down now. Is the water coming in? No! Not at all! Look, there is a thin little line of water just at the bottom of the tube. Why does the water not come in? Because the tube is not empty; it is full of air, and the air is keeping the water out.

From this experiment we learn that air is present in so-called "empty" vessels.

I drop this solid lump of sugar into this glass of water. What do you see? Bubbles of air come off as the sugar melts, so we see that air is locked up in the sugar. I now drop this little lump of dry earth into water. What do you see? The water drives off from it little bubbles of air; so we learn that air is in the soil when it is *dry*. Of course, if the soil is very wet the water may have driven out all the air and we should see no bubbles when we dropped it in. Sometimes after rain, air gets driven down into the soil and imprisoned in it, or driven on for quite long distances. Sometimes it comes up into people's houses. Now the air in the soil may be very impure air; that is, it may be full of dangerous gases from decaying things, or have bad air from leaking drains in it. It cannot be wholesome to have air like that in our houses. In some towns they are particular to make

people build their houses so that the air in the soil cannot get in. In Staffordshire, where people often have to live over old mines, some people have died because the air from the mines has got into their houses, through the ground, when the mine happened to be on fire. We call air when it is in the soil, *ground air*.

Is there any air in water? Let us see. I have been warming this flask of water over the lamp. It is not yet boiling, but do you notice anything? Yes, there are quantities of tiny bubbles rising through the water. If now the water should boil we should have a great bubbling going on. Those big bubbles are mostly water turned into gas, or "water vapour," as it is called, but air also comes off. Have you ever drunk boiled water? How did it taste? Very flat. That is because the air was driven off. Fish have to get the special air they want out of the water round them, just as we get the particular air *we* want out of the atmosphere round ourselves; but if you put fish into water which has been boiled they will gasp for breath and die of suffocation, because there is no air left. So we have learnt that air is present in water. It seems to be everywhere, does it not?

I will put on the blackboard what we have learnt by our experiments:—

"Air is present everywhere—in so-called empty vessels, in soil, in the food we eat and in the water we drink."

Properties of Air.—"Light as air," we say. But air has weight. If I take a balance and put a flask full of air on one side and another flask exactly like it on the other, the balance will be quite even, because they both weigh the same. But if I now have an air-pump and take some of the air out of one flask, and then weigh it again, you would see that the scale went up, because the other flask, which had not been touched, would weigh heavier. So *air has weight.*

Air can press hard because it has weight. Here is a glass with a smooth, straight rim. I will fill it full of water first. *Quite* full. Now I will put this flat piece of card over the top and quickly turn the glass right over, holding it up in the air, mouth downwards. You see the card does not fall off, neither does the water run out. See! I will turn it upwards and downwards several times running and yet it acts in just the same way. Why does the water not run out? Because the air is pressing on the cardboard outside and pressing it as hard as it can against the edge of the glass; also because the inside of the glass is filled with water and not with air, and the water does not press so hard as the air does. From this we see that air presses and has weight. It presses in all directions, upwards and downwards, and from side to side. If it only pressed downwards we should all be crushed to death with about a hundred-mile thickness of air pressing on us. We should

be flatter than if a steam-roller had rolled over us. Air is pressing in all directions at the rate of 15 lbs. to every square inch of surface. Measure a square inch and see how little it is. You have a good many square inches on the surface of your body, have you not? A grown-up man has still more, and if we added all the square inches together and multiplied them by 15 lbs. we should find out that a grown man was being pressed upon by over *14 tons* of air. But it is not only pressing on the outside of his body; it is inside the body too, and so he does not feel the pressure in the least. If you were pressing against one side of an open door with all your might, and another person, just as strong as you are, were on the other side of the door and pressing just exactly as hard as you, what would happen? The door would not move at all. It would act just as though nobody was touching it. So in the same way we do not feel the air pressing on us, because it is pressing from all sides *at the same time.*

If, now, we go up a high mountain, the air will not press quite so hard, because we have gone up a little of the hundred miles, and there are not quite a hundred miles of air pressing on us from above. Besides that, we are further away from the great mass of the earth, which like a great magnet is pulling us and the air towards it. Try to pull this needle away from the magnet. It is sticking hard and needs quite a sharp pull to get it off. Now hold the needle as close as you can without touching the magnet. What do you feel? The needle seems to be trying to get to the magnet. A stone is not heavy in itself: it is only heavy because the earth attracts and pulls it to itself more than it pulls a feather. Air has, therefore, weight because the earth is pulling at it, and the further we get away from the earth the less we and the air will feel the pull. The air gets very much spread out when it is far away from the earth, and there is too little of it on the tops of high mountains for us to be able to breathe properly. It is thin air, or what is called *rarefied* air. If we could go up 18,000 feet, we should find the pressure half what it is at sea-level. For whereas at sea-level the pressure of the atmosphere can hold up nearly 30 inches of mercury, at 18,000 feet, or about 3½ miles, it can only hold up 15 inches. If it were possible to dig a pit in the earth 50 miles deep, the air at the bottom would be pressed so thick that it could be cut with a knife, as you would cut cheese.

(If the teacher has the opportunity, the fact of the power of the atmosphere to support 30 inches of mercury should be demonstrated.)

We have seen that there is air in water. It is partly because the air is pressing on the water so hard that it gets into it; but we see that if we heat water till it "boils," as we say, the air and water vapour fly off. Why does the air fly off? It flies off because it is hot,

and hot air, being lighter than cold air, will try and rise up in the atmosphere, which is like a great sea of air. But air gets cold again very soon, and then it loses its power of rising and will fall down. Now you know a little of what happens when water boils. Air and water vapour are passing off into the atmosphere, and the more heavily the atmosphere is pressing on the water the more difficult is the process, and the hotter the water has to be before the bubbles rise up, which we call boiling.

Water at sea-level boils at 212° F. If only a part of that weight of air were pressing on the water, it would boil before it got as hot as at sea-level.

When people go up very high mountains they find the water boils so soon that they cannot cook certain things, as it is not hot enough. Perhaps some of you will study chemistry and physics some day, and they will tell you a great deal more about these things. You will understand now why, in a deep mine, the kettle takes longer to boil and the water is hotter. On some days, too, just here where we are living, the weight of the atmosphere is a little greater than usual, and then we say we have a high barometer, and really the kettle does not boil quite so fast, but it is so small a difference that we do not notice it. It boils more quickly when the barometer is low—that is, when the atmosphere is not quite heavy enough to hold up 30 inches of mercury, but is only holding up 29 or perhaps 28 inches. The air is lighter when it has much water vapour in it, for water vapour is lighter than air, and therefore air which is very full of water vapour does not press heavily enough to hold up as much mercury as that which dry air, at the same temperature, can hold up. When that is the case, the mercury, or quicksilver as it is often called, will naturally sink in the barometer, and we say, "It is going to rain." How can we tell that air holds water? Here I have a tin cup, and I will put either ice or very cold water into it. Now that we have waited a little, what do we see? A film of mist on the outside of the cup. Where has that mist come from? It has come from the air. Warm air can hold a good deal of water in the form of vapour—that is to say, in the form of an invisible gas. Cold air, however, cannot hold as much. The air round the tin cup has touched the tin, which is very cold, and it has chilled the air so much that it can no longer hold all the water which was in it before, therefore the water vapour becomes deposited in the form of liquid water on the cold cup.

We learn from this little experiment *that air holds water, and that hot air can hold more water than cold air.* We also begin to understand why air at night deposits dew, and why cold walls and stones are often running with moisture in autumn, when air holds a great deal of water.

Water vapour coming out of the spout of a kettle can be seen because it is very hot, and when it touches the cold air it is chilled down and becomes water once more. It is not steam. Real steam is water in the form of a gas and is quite invisible. Now that this flask of water is boiling, what do you see? The water is bubbling furiously, and bubbles of water vapour are coming off, but above the water there seems nothing—yet steam is there, for the water is boiling away as it is turned into steam. Can you see anything else? Yes; white vapour coming out of the neck of the flask, just as we can see it coming out of the spout when the kettle boils. If you look very carefully, you will see, both in the flask and in the kettle, that, just near the neck or spout, there is nothing to be seen at all. Yet something is there. That something is invisible steam: then a little further the hot steam is condensed by the cold air and turned into water and looks like a cloud of fine smoke. But it is all water really. Now, if I put a lighted match or a Bunsen burner under a cloud of vapour, what happens? It disappears again. Why? Because it is still very hot and the heat has turned it into steam once more.

Here is a large test-tube, whose mouth is covered with a piece of fine rubber tissue. This tissue stretches a great deal, and I have cut off a piece large enough to cover the mouth of the test-tube, and have tied it firmly round it, just as one stretches paper over a jam-pot. I had to be very careful to stretch the tissue a little but not very much, and then I had to be very careful to wind the piece of silk round the rubber and the neck very tightly indeed and very evenly, so that no air can escape. I had also to see that there were no creases at the edge of the test-tube, but that the rubber was lying very smoothly. Now I will hold the test-tube by the mouth end and pass all the rest of it through the flame of either a Bunsen burner or a spirit-lamp, until it is very hot indeed. What happens? Look carefully and tell me. *The rubber tissue begins to bulge out.* If we go on we can make it look like a big bubble of indiarubber. Why does it act like this? Evidently we have altered the state of the air inside by heating it. The air tries to fill a larger space, or *expands* as we say, and presses so hard against the sides of the tube and against the rubber that it pushes the elastic rubber out.

We learn from this experiment that air when heated swells out and tries to take up more room, or, in a more scientific way of talking, *it increases in volume*—so we again put the fact into other words, and we say that *hot air expands.*

By now this tube has cooled a little, and being made of very thin glass which does not crack easily in alterations of temperature, we will plunge it straight down into this vessel full of very cold water. What is

happening to the rubber tissue? The bubble is going down fast as we chill the air inside, and now it is quite flat again, as it was when we began; but we will keep the tube in the cold water a little longer, and if we had ice we might even drop some in. Now the rubber is beginning to look as if it were being pushed into the tube. There is quite a depression like a little cup. Now it is much deeper, and once more there is a bubble of rubber, only this time the bubble is actually inside the tube! We must not hold it in the cold water any longer or else it may even burst the rubber. What is the cause of this? We have once again evidently altered the state of the air inside the tube and have made it try to take up less room. Therefore it is not pressing so hard on the rubber; but nevertheless the air outside is pressing as hard as before, therefore, as it finds that the air on the other side is not pressing as hard as it itself is doing, it manages to push the rubber right in.

What do we learn from this experiment? We learn that if we chill air down it will tend to take up less room and it does not press so hard; so we say, *air contracts by cold.*

I have here a paper spiral, made by drawing a spiral line round and round on a piece of paper and then cutting along it; a wood shaving will also do, but not quite so well. I will now put a pin through the last little curl of the spiral and hold the whole thing up by the pointed end of the pin, with the narrow spirals upwards. Now I will put a spirit-lamp or Bunsen burner under it. What happens? The spiral turns round and round, at first slowly and then very quickly. Why does it do this? It does it because the hot air above the lamp expands, and, being lighter by expansion, it rises, and a current of air going upwards hits against the turns of the spiral and drives it round.

We learn from this experiment that *hot air rises.* A balloon filled with hot air will rise. There are many other things we could do to find out more about air, but we have not time to do them all. Here is one more, however. I have an ordinary medicine bottle here, with a well-fitting cork, through which passes a glass tube, which also fits the hole very tightly. The glass tube passes down nearly to the bottom of the bottle. The bottle is what people call "half empty"—that is, it is half full of water, which I have coloured pink, and half full of air. If I blow down into the bottle, I shall be putting more air into the bottle than it holds naturally at the ordinary pressure of the atmosphere. Where will the air go which I blow in? It will come up through the water and join the air at the top of the bottle. But if the half of the bottle were full of air before and more is now coming in, what will have to happen? It will be like a railway carriage when it is full and many more people squeeze in: the others will all have to sit more closely together in order to make room. So the air will be pressed together like

the people in the railway carriage—*compressed*, as we say. See, I am going to blow down very strongly indeed, and with a good long breath; then I shall take my mouth away suddenly from the end of the tube, and you must tell me what happens, and why. What do you notice? The pink water rushed up the tube nearly into my face directly I stopped blowing and took my mouth away quickly from the end of the tube. Why did it do that? The air rebounded directly I took the extra pressure off, and pressed so hard on the surface of the water in the bottle, pressing harder than the air outside was pressing, that it forced the water right up the tube. You see from this that we can compress air and make it take up less room; but when we take the extra pressure off, it will jump back to its original bulk, and if the pressure is great it will do it with great force. If you pull a piece of elastic very hard and then let it go, you know how quickly it will snap back. When you pull the elastic you make it take up more room than it wants to take up. But when you compress air you make it take up less room than it wants to take up; therefore, directly you take the pressure off, back snaps the extra air, and if anything is in the way the air will carry it along too. This is how air acts in some explosions, and why walls, and windows, and doors are sometimes blown out or blown in. So we learn from this experiment that *air is elastic.*

Can you think of any other way of showing that air is elastic? Have you ever blown up a bicycle tire? When the tire is flat, is there air inside? Yes. At what pressure is that air? At the same pressure as the air outside, and not pressing strongly enough inside, therefore, to hold out the heavy rubber tube. When you blow the tire up with a pump, what are you really doing? Putting more air in than there is room for at the ordinary pressure, so that you are forced to press hard to blow the extra air in and *compress* it. The more air gets in, the harder you have to press and pump to make room for still more. If you loosen the valve or get a puncture, the compressed air will rush out at once. You can only keep it in by force.

Now I am going to burn this pastille far away in the other corner of the class-room. It is a long way from you. Do you notice anything? Yes, a sweet perfume. What does this show? It shows that the air containing the perfume must have moved to where you are sitting. Have you noticed that when something is burnt in the kitchen of a house, something which smells very strongly, perhaps grease or strong tobacco, you can smell it right up in some room far away? The air has moved to the other room. This power of air to mix and move without being driven is called *the power of diffusion.*

So now let us see what we have learnt about air:—

1. Air is present everywhere—in so-called empty vessels, in soil, in the food we eat and the water we drink.

2. It presses in all directions, at the rate of 15 lbs. to the square inch, and will, at sea-level, hold up nearly 30 inches of mercury.

3. Air has weight.

4. Air contains water in the form of vapour.

5. Heated air expands and can hold more water than chilled air, which contracts and deposits water.

6. Hot air is light and rises, while cold air is heavy and falls.

7. Air is elastic and can be compressed.

8. Air diffuses.

Note.—The blackboard summary has been condensed as much as possible, so as to fit it to form the subject of a composition for the scholars, and in order to minimise the burden on the memory.

CHAPTER X.

THE AIR WE BREATHE—*continued.*

Necessary Apparatus.

Exp. I.
- A bell-jar and stopper, the latter well greased.
- Large, thin, flat cork.
- A little phosphorus in a bottle of water.
- A taper.

Caution.—Cut the phosphorus only under water. On no account handle it. Dry it cautiously on blotting-paper before placing it on the cork. Light it as soon as possible afterwards, otherwise it may ignite spontaneously before you are ready.

Exp. II.
- A small glass tumbler.
- A little clear limewater.
- A glass tube or straw.

Exp. III.
- A saucer or dish of water.
- A glass jar or large tumbler, filled with freshly drawn water.
- A piece of cardboard.
- A bunch of fresh green leaves.

We have learnt a good deal about what air can *do*; suppose now that we try and find out a little about what it has *in it*. What is air made of? Have you ever thought how wonderful it is that some of the most powerful and necessary things in the world are invisible? We cannot see electricity, and yet it lights our houses, drives our trains and our trams, and carries our messages across the ocean and the land, and does many other wonderful things. We cannot see air, but we have seen how strong air is, and we know that if we did not get air to breathe we should die in a few seconds.

Young people are usually fond of pulling things to pieces to see how they are made. Many boys have pulled old clocks to pieces, many girls have broken up their toys to see how they were put together! That curiosity to know about things has been present in the race of men for thousands and thousands of years. When you pull something to pieces and find out what the different materials are of which it is made, you may be said to have dissected and analysed it. When men pulled things to pieces they could measure

and weigh the different materials, and so were able to say, "This thing contains just so much of this material, and just so much of this other material, and no more." They continually found matter which they could not break up into anything else, and they then called it an *element*. They called gold an element because they could not find anything else in it but gold. They analysed such substances as clay, and they found that clay was not an element, for it could be divided into two things, silica and aluminium. Clay is made up (*compounded*, as we say) of these two substances. But they found that they could not discover anything else in silica but silica itself, nor anything else in aluminium but aluminium itself, and so they learnt that silica and aluminium are elements, and that clay is a compound of them.

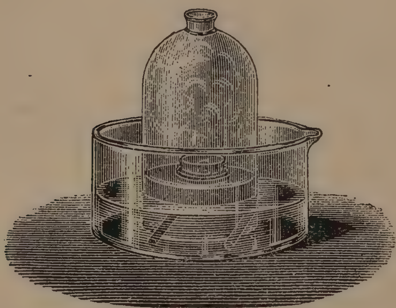


FIG. 40.—Burning Phosphorus.

But they made mistakes. We have already heard about them. They could not find out, for instance, any way to analyse air or water, and so they came to the conclusion that these were elements too. Later on it was discovered that both air and water were not elements at all, but were made of several elements. Let us see if we can find out something about air for ourselves. Here is a bell-jar. You see that it has no bottom. Here I have a large, flat cork, and I will make a little hollow in the centre, so as to hold safely something I am going to put on it. I will grease the stopper so as to make the bell-jar quite air-tight above. Now I will float the cork on the water in this basin, and in the hollow I will put this little bit of dry phosphorus, the size of a small pea. *Never* touch phosphorus with your fingers, or you will get a bad burn; *never* rub phosphorus unless you want it to catch fire; always remember that unless you keep it under water it is liable to burst into flame *by itself* at any moment. It is *very* dangerous to handle. Now, before I cover the cork up by putting the bell-jar straight down into the water over it, I will first show you that this taper will not go out if I put it into the jar, but burns brightly for the second or two I hold it there. Now I put the bell-jar into the basin, into which I have been careful to put plenty of water, but first I must set fire to the phosphorus with a match or a hot glass rod. See how brightly the phosphorus burns inside the jar! I just steady the jar a little,

because something is making it rock about, but I am careful not to press it down. What has happened? (*a*) *The phosphorus has stopped burning, though there is still some of it left.* (*b*) *The jar also is full of white fumes.* (*c*) *There is more water in the jar.* We will now wait till the white fumes have cleared away, and in the meantime perhaps we can do something else.

Now the fumes have gone. Is there as much air inside as there was before? No, evidently not. There is a great deal more water in now, and the water is much higher than the level of the water in the basin. Do you remember what we said would happen if a door were half open, and someone on one side were pushing it to, and someone else on the other side were trying to push it wide open? Yes, we remember that if both were equally strong and pushing their hardest, the door would stay half open. But here the water has moved, has it not? What does that show? It shows that the air outside the jar is pressing now more strongly on the water than the air inside the jar, since it has been able to push the water right inside, which it could not do before when the air on both sides was pressing equally. What does this show? It shows that by burning the phosphorus we have altered the air in such a way that it cannot press so strongly. Something which helped to press has gone out of the air and has gone into the white fumes, which have now been absorbed. How hard is the outside air pressing? At the rate of about 15 lbs. to the square inch. The inside air is now evidently pressing less strongly. Now I will measure how much air has gone. About one-fifth of the amount has disappeared. I am now going to take the stopper out and put this lighted taper down. Watch and tell me what happens. The taper goes out. Why? Because something has gone out of the air which allowed it to burn before. That something is a gas called oxygen, which, as we see, forms about one-fifth of the atmosphere. The other part of the air, which is left behind, is called nitrogen, and over three-quarters of the atmosphere is made up of it. Phosphorus is very greedy for oxygen, and will always use it up if it gets the chance. In this case the phosphorus was not all finished, so it is evident that the oxygen was finished first. We must be careful to see that no one gets burnt by the little bit of phosphorus left on the cork. Whenever oxygen unites with any other substance, a compound is formed and heat is produced. When a piece of iron rusts, the rust is different from the iron: it is a combination of oxygen and iron. When you pour water over quicklime, oxygen is joining on, "uniting," to the lime and forming a new kind of substance, and heat is given off. Do you understand why the taper went out? There was no more oxygen left to join on to what the taper was made of and create heat and light. So we learn

from this experiment that in every 100 parts of air there are about 21 parts of oxygen and about 79 parts of nitrogen, and that things will burn where there is oxygen, but will not burn where there is only nitrogen.

Are you all warm? Or are you as cold as the rocks, or the stones outside, or even as the trees? You are much warmer. Why are you warm? You are warm because you are burning, because oxygen is getting into your bodies and uniting with something it finds there and so heat is produced. In short, we are all burning away, as the phosphorus burnt, only we burn too slowly to give out a light. When coal burns in the grate it is uniting with oxygen very fast and giving out light and heat. When we want the fire to burn up we stir it, or we blow air into it with the bellows, so as to give it more oxygen. How do we get our oxygen? We get it through our nose and mouth when we breathe. Where do we get the coal for our bodies? We get it from the food we eat. How careful we ought to be, then, to get pure air, with plenty of oxygen in it, so that our fires may burn brightly! Now I will put on the blackboard what we have learnt:—

Air contains two gases: one which will not let things burn in it (support combustion) and is called nitrogen, and another which will let things burn in it and is called oxygen.

Now, oxygen is the breath of life. We take oxygen in every time we breathe, and this oxygen unites with an element it finds in our body. That element is called *carbon*. When the phosphorus and the oxygen unite, white fumes are formed. The oxygen and the carbon, however, do not form white fumes, but a gas called carbon dioxide gas. That is a compound, of course, and it contains one part of carbon to two parts of oxygen. There is always a little trace of this gas in atmospheric air, if you examine 100 parts. Of course, if you examined as much as 10,000 parts of air you would get a larger amount. In 10,000 parts of air you would find something like—

Nitrogen	7,900
Oxygen	2,096
Carbon dioxide	4
	10,000

Now, if, inside our bodies, oxygen is uniting with carbon and forming dioxide gas, is there any way in which we can demonstrate it? The expression *demonstrate* means, to *show to be true*. Here is a perfectly clean bottle, into which I have put some very clear lime-water; I have not filled the bottle up with the water, but have left some air in. Now, if carbon dioxide gas is put into limewater, it has the

power of turning the limewater milky. I will cork the bottle and shake the limewater and air up together. Is there any change? No, or so little that we can hardly notice it. That shows us that there is very little carbon dioxide in the air we draw in, or *inspire*—only 4 parts in 10,000 in very pure air, as we know, though I am afraid there is a good deal more than that in most rooms. Now, I will take this straw and put it into the limewater, and I will take a good deep breath of this air we have been shaking up, and I will blow it through the limewater, after it has been in my body. Do you notice any change? Yes, *the limewater has become very milky.* What does that show? It shows that a lot of carbon dioxide is formed in the body and comes away when we breathe out, or *expire*, as we say.

Now, if we analyse breathed-out air, we find that it contains, in 10,000 parts, something like—

Nitrogen	7,900
Oxygen	1,630
Carbon dioxide	470
	10,000

So you see that about a third of the oxygen has been used up, and the carbon dioxide has been made out of it and has increased more than a hundred times. We shall see more about this when we are learning about breathing. Carbon dioxide breathed out is very bad for us to breathe over again, so we must try and get as little of it as possible. It is a heavy gas, and collects in old wells and old shafts, where air does not diffuse easily. People cannot breathe in it, because they cannot get oxygen, and fire will not burn in it. If a man has to go down an old well, he lets a candle down first. If the candle goes out, he knows that the well is full of carbon dioxide, for the candle will not burn without oxygen; that means that it is not safe for him to go down, because he needs more oxygen than the candle, and would die of suffocation down there, just as it did. If the candle burns brightly, he knows it is safe for him too.

Do plants breathe? Yes, plants breathe, as men and animals do, because they need oxygen, though they do not need as much as animals; but they have to get their food out of Nature's two great store-cupboards. One store-cupboard is the earth and another is the air. The plant takes the carbon dioxide, as well as a little oxygen, out of the air and splits it up into carbon and oxygen. It keeps the carbon, but it lets some of the oxygen out again for men and animals to breathe. Plants are very wonderful things, for they take the carbon, together with some oxygen and a gas called hydrogen, which they get

out of water, and they build it up into sugar, and starch, and oil. (The teacher should make the children give examples—sugar-cane, arrowroot, olive-oil, etc.) Let us see if we can discover them breathing out oxygen. Here is some fresh water-cress, which I put into a big glass jar. I fill the glass full of fresh spring water. Spring water has much carbon dioxide gas in it. I then turn the glass jar over into a dish with a little water in it. I can do that easily by first putting a card over the mouth of the jar and then slipping it away when I have the mouth under water. In this way there was no bubble of air in the jar, but it was quite full of water. Then I put the jar into the sunshine for an hour or two. What do you notice? The leaves and stems are all covered over with tiny bubbles, and a quantity of these bubbles have collected at the top of the jar. These bubbles are oxygen gas. Where have they come from? The plant has got them from the air, which we learnt, in another lesson, is present in water. It has breathed in the carbon dioxide of the air dissolved in the water; it has kept the carbon and is building it up into its leaves and stems, but it has let the oxygen out. Would it do the same if we had put it into boiled water? No. Why? Because, as we have learnt, air is driven off from boiled water. Here is another jar which I prepared at the same time, but, instead of putting it into the sunshine, I put it into a dark cupboard. Are there any bubbles of oxygen? No. That is because green plants can only decompose the carbon dioxide if they get sunlight; green plants cannot grow in the dark.

We learn from these experiments that animals and plants help each other. Men and animals breathe out carbon dioxide gas, which in large quantities is a poison; but plants breathe in carbon dioxide and make the carbon into useful things, and let out the pure oxygen for men and animals to breathe. Plants, then, tend to purify the air and make it fit for us. How useful those people must be who cause trees to be planted in the streets of our towns where the air is not very good! (If the teacher has a hand lens she should show the children the stomata on the leaves before continuing.) Smoke is not good for plants, because it chokes up their poor little mouths and makes it difficult for them to breathe; but some kinds will do fairly well if the air is not very bad, and they help to make it fresher and purer. We will remember that now, will we not, when we see trees growing in the towns? Perhaps some of us one day will help to make the air in towns purer by planting trees, or at all events by taking care of them when they are planted, and seeing that no one is so dishonest, or so careless, or so selfish as to injure them for his own amusement.

Now I will write upon the blackboard some of the things we have learnt:—

1. Pure air contains nitrogen and oxygen gas and a very little carbon dioxide.

2. Breathed air contains the same amount of nitrogen but less oxygen, and a great deal of carbon dioxide.

3. Oxygen is the breath of life, and fire will burn in it.

4. Carbon dioxide, when breathed out, or in any quantity, acts like a poison, and fire will not burn in it.

Plants breathe in carbon dioxide and let out oxygen, and so help to purify the air.

Note.—The blackboard summary has been shortened as much as possible; but as it omits several points which have been learnt, the teacher can, at discretion, include them for higher standards.

CHAPTER XI.

THE LUNGS, AND HOW WE BREATHE.

Necessary Apparatus.

Thermometer.
Tape-measure.
Small mirror.
Wide-mouthed bottle, fitted with cork pierced with two holes, through which are passed two long glass tubes.
Limewater.

Suggested Apparatus.

Sheep's lungs.
Pair of strong scissors.
Bellows.
Piece of string.

We have now to learn how the air we breathe gets into the body and is able to be carried to every part. Certain cells have formed themselves into special apparatus to convey the air, and one of these organs is the nose. Very dry air would irritate the throat and lungs, but air breathed through the nose takes up water from the damp mucous membrane inside the nostrils and becomes saturated. The mucous membrane is very full of blood-vessels, and lies over some curious little bones which raise it up and give it greater surface, so that the air as it passes becomes well warmed, however cold it may be when breathed in. This membrane, being damp and coated with slightly sticky matter, catches and holds dust and germs and so prevents them from going down to the back of the throat and irritating it, and from passing down into the lungs, where they would do great harm. We shall hear more about this in another lesson, but now we will remember that in the nose air is warmed, moistened, and purified. It is a very bad habit to breathe through the mouth, which cannot purify the air properly; and doing so leads to many colds and also to lung diseases, as well as nose and throat troubles and bad teeth. Everybody ought to learn to breathe through the nose. After leaving the back of the throat the air passes into the voice-box (larynx), where the vocal cords are which we use in speaking; then it goes down the windpipe (trachea), which is a continuation of the voice-box and is about four inches long. The windpipe is about as thick as your middle finger, and has stiff walls kept open by rings of gristle, which do not quite meet behind. When

the upper part of the chest is reached the windpipe divides into two parts, which are called the bronchial tubes. These two branches go to right and left, entering into and forming part of the important breathing organs called the lungs, situated one on each side of the chest. The tubes branch out in all directions through both lungs. The lungs and the heart are the two great organs in the chest.[1] The

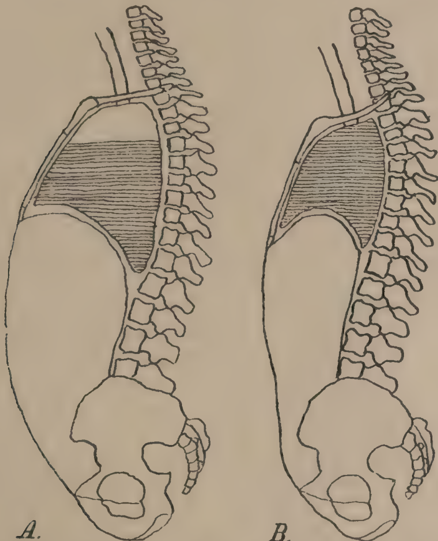


Fig. 41.—Diagram of Diaphragm during (A) Inhalation and (B) Exhalation.

chest is separated from the rest of the body by the midriff (diaphragm), which forms a sort of movable floor and is used in breathing (fig. 41.)

[Note:—*The following will need modification if diagrams are used instead of the actual sheep's lungs.*]

Here are sheep's lungs: the butcher calls them *lights*, because they are so light and full of air that they will float in water. What colour are they? *Pink.* They are also soft and spongy. What is the skin like which covers them? *Shiny and smooth.* This skin is called the *pleura*, and it also lines the inside of the chest, and its cells pour out a little fluid which is just enough to make it easy for the lungs to slip up and down smoothly in the movements of breathing, although pressing closely on the chest wall. In *pleurisy* this membrane is inflamed and

[1] See fig. 27, p. 33.

pours out too much fluid. Notice the windpipe with its rings of gristle. It is much longer in a sheep than it is in us, for a sheep has a longer neck than we have. It must be very long indeed in a giraffe. The inside of the windpipe and the bronchial tubes is lined with a delicate smooth skin made of layers of cells one on the top of each other, the cells of the top layer having fine hairs (cilia) projecting from them. These cells are the *sweeper cells* of the air-passages, and they keep the little hair-like ends moving rapidly in an upward direction, and so sweep away any dust or germ that manage to get past the nose and mouth.[1] Mouth-breathers give them more work to do, for more dust gets in; they line all the bronchial tubes and never stop working day or night, sweeping out the air-passages and keeping the lungs free. Now we will take this pair of strong scissors and cut open this bronchial tube as it enters the lung, and we will keep on cutting along it as far as we can. What does it look like inside? Smooth and shiny. Do you notice anything else? Yes, little openings. What are these openings? They are smaller branches of the main bronchial tube leading off to different parts of the lung. Now the tube is getting smaller and smaller and the rings of cartilage have turned to flat discs, but still the tubes keep open. Now we seem to come to an end, but in reality, if we could see through a microscope, we should learn that the tube still continues, only it is now very fine indeed—a capillary tube, in fact. At the end it widens out a little into a sort of little sac (infundibulum). Round this widening are little divisions, called *air-cells*. You must not confuse these with ordinary "cells" such as we have so often heard about, for the word here is used to mean a much larger division or chamber. The walls of these air-cells are very thin and are made of body cells, and outside the wall run tiny capillary blood-vessels with very thin walls also, so there is very little to separate the air in the air-cell from the blood in the blood-

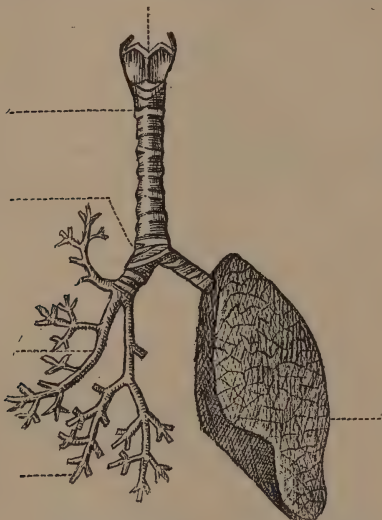


Fig. 42.—Diagram of Lungs to show branching of Air-Passages.

[1] See fig. 43 on following page.

vessels. Which side of the heart sends blood to the lungs? The right side. Why? To get rid of its impurity, carbon dioxide, and to get fresh air in the form of oxygen. What is the blood-vessel called which brings the blood? The lung artery (pulmonary artery). Let us see if we can find a branch of it at the root of the lung. Here it is, and we can cut down it and find lots of branches going to every part of the lung. Here is a measuring-tape which I will put round my chest while I let my breath out, and I will measure how much round it is, and hold it there while I take a long, deep breath. What happens? I have to let the measuring-tape out. Why? Because the chest has grown larger.[1] Yes, when we

FIG. 43.—Sweeper Cells.

breathe, a message comes down from the brain and tells the breathing muscles that there is too much carbon dioxide in the blood, so they at once set to work. The muscles in the midriff answer to the stimulus and get short and thick and so pull the floor of the chest down, and the other breathing muscles between the ribs also shorten and pull the sloping ribs

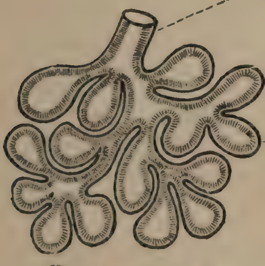


FIG. 44.—Air-Cells of Lung.

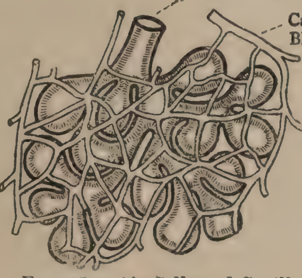


FIG. 45.—Air-Cells and Capillaries.

up and push the breastbone forward, so that the whole chest increases in size, perhaps as much as three inches round in a grown man. Now what happens? How much is the air pressing inside? At the rate of 15 lbs. to the square inch, of course. But now that there is more room inside, more could get in, could it not? So what will happen? There will be less pressure, for the air will spread itself out over the bigger space, and the outside air, which is pressing as hard as ever, will run down the windpipe into the lungs and once more make the pressure equal.

[1] See fig. 41, p. 71.

In this new air will be plenty of oxygen. We could get no air at all if the chest did not move. People who have been covered up by a fall of earth on the top of them have sometimes died of want of air although their noses and mouths were uncovered, for the weight of earth on their body made it impossible for the muscles to move, and, the air pressure being the same inside and out, practically no air could move into their

Fig. 46.—Semi-diagrammatic representation of the Air-Vesicles of the Lung. *vv*, blood-vessels at margin of alveolus. *cc*, blood-capillaries. E, squamous epithelium. *f*, alveolar epithelium. *ee*, elastic tissue.

lungs or come out of them. So we see how important it is not to wear clothes which prevent the proper movements of the breathing muscles. Silly girls who wear tight stays prevent the midriff from moving and also the lower ribs, therefore less air gets into the chest than ought to, and they are apt to get weak and pale and suffer from indigestion. It is also a great mistake to wear anything tight across the chest, and especially when we are taking hard exercise; indeed, then it is positively dangerous.

I will now put the nozzle of this pair of bellows into the bronchial tube of the lung which we have not cut open, and then tie a string firmly round, and blow. What happens? The lung gets larger and paler and swells up full of air. You can now understand what goes on when we breathe. The chest enlarges, the elastic lungs get pushed out by the air rushing down into them and they fill up the enlarged chest, the fresh oxygen in the air-cell passes through its wall and gets through the equally thin wall of the capillary blood-vessel and so into the blood, where the pressure of it is low. Now the red corpuscle seizes hold of it and rushes away through the pulmonary veins to the left side of the heart. But the blood was full of carbon dioxide; what becomes of that? It passes out from the blood *into* the air-cell. Does it stay there? No. The midriff comes up, the ribs fall down, the breastbone moves back, the lung gets squeezed by them all, the air is pushed up the windpipe and we breathe it out. It seems from this that the air we breathe out must be very different from the air we breathe in. Let us see if we can find out anything about it. Here is a thermometer. What is the temperature of this room? Sixty degrees. Now I will breathe hard on the bulb of the thermometer, holding my mouth rather wide open and quite close to it for about a minute and breathing in through my nose. What has happened? The thermometer shows a temperature of over 90°! The air has been warmed very much, evidently. Now, the temperature of the blood is 98·4°, so we learn that breathed-out air, however cold it was when it went in, is warmed up nearly to the temperature of the blood when it comes out. Here is a little bit of looking-glass; it is quite clear and bright. I will breathe on it. What happens? It becomes covered with a film of moisture. Where has that moisture come from? Was it in the air before it was breathed? No, so it has come from inside the body, and the warm air was full of it, but directly the air got cooled again it could not hold so much, and therefore deposited it on the glass. Do you remember the experiment we made with the tin cup full of ice, and how we chilled the air of the room down and made it drop the water it was carrying? What do we learn from our experiment? That breathed-out air is saturated with water. If several people are sitting in a room or a railway carriage on a cold day, their breath, full of water from the breathing passages, touches the cold windows and gets so chilled that it has to drop the extra moisture it is carrying and the windows get thick with mist, which gradually runs down and forms little pools of water. It is strange to think that this water has come out of the blood, and it shows us that the lungs are constantly getting rid of moisture as long as the air which we breathe in can hold any more. We will make one more experiment.

Here is a bottle with a wide mouth, fitted with a cork, through which are pierced two holes, and through the holes run two long pieces of glass tubing. The bottle is half full of limewater and half full of air, and one of the tubes dips down into the air and the other dips down into the water. Now, if we make air bubble through limewater, the lime will combine with any carbon dioxide in the air and form chalk, which we can see. First, then, we will try to find out if there is much of this unwholesome gas in the air of this room. Let us hope not, for we are very careful to keep the windows open to let it out when we breathe it from our lungs, so that the trees and plants outside can get it and make it into sugar, and starch, and oily things, and set the oxygen free again for us to use. How shall we get the air to bubble through? Blow it through? If we do, it will have to pass through our lungs first, and that is just what we do not want it to do. How can we manage it? Do you think what we learnt about air pressure will help us? How hard is the air inside the bottle pressing? Just as hard as the air outside. If we could take some of that air out, there would be less pressure; is that not so? Yes. What would happen? The air pressing down the tubes would get in because it would be pressing harder. Yes, that is right. So now I will put my mouth to the tube which dips down into the air only and suck some out, and then air will have to press in through the other tube; but as the other tube dips right into the water, the air will have to pass through the water to get into the air space on the other side, and if there is much carbon dioxide present the water will look chalky. Now I will empty my lungs and take a good pull of air out of the bottle and drag more air into it. One! No change? I will do it twice more. Any change? Yes, a very little change is there, if you look closely, but it is so little that it shows there can be very little carbon dioxide in good fresh air, such as we have in this room. Now I will drive air through the water by breathing down the other tube. It will be *just the same air*, the only difference will be that it has passed through my lungs first. I will do it slowly three times. I will take a good deep breath of air, and then blow into the limewater. One! Two! Three! What has happened? The water has got white and thick like milk, and if you look at it closely you will see it is full of chalk floating about. What does that show? It shows that air from the lungs is full of carbon dioxide. Now carbon dioxide is a poison to human beings. But breathed-out air has got worn-out waste matter as well. Air in inhabited rooms gets impure from gases given off from the breathing passages and skin, even with clean people present, and is much worse when people have dirty skins and bad teeth and dirty clothes. These matters "go bad" very quickly and give air a stuffy, close, unpleasant smell, and are very poisonous to breathe. People who

have been shut up in rooms without air have died from want of oxygen, and because of the carbon dioxide in their blood of which they could not get rid, as in the well-known history of the Black Hole of Calcutta; but those who managed to crawl alive out of that Black Hole were very ill with putrid fever, because of the poisonous waste matter in the air, polluted by the breathing and by the skins of so many people. If we get ourselves into the habit of living in stuffy rooms and sleeping in stuffy bedrooms, with the windows tightly shut and the chimney blocked up, we may not die of it in any direct way, but we make ourselves liable to colds and coughs, and we make our blood poor and thin, and our nerves get weakened, and perhaps we become delicate and consumptive. It is very difficult to do lessons properly in stuffy air, because the brain does not get rid of the poisonous carbon dioxide properly, and we get sleepy, and dull, and stupid. Stooping over desks is bad for us too, for it makes the chest narrow, and then the lungs cannot fill out properly and purify the blood. Deep-breathing exercises are very good for us, especially helping us to move the midriff properly, and every time the midriff moves down it squeezes the liver and sends the blood on to the right side of the heart, and so improves the circulation and the purity of the blood at the same time. We must, however, always be careful to do these exercises in good air, with windows open, because of course we are getting rid of a lot of carbon dioxide. Quick brisk exercises, which make us take deep breaths, are splendid for making us strong and healthy. We must never be loafers. Loafing is bad for brain and body and is a very different thing from resting. We will always try to get plenty of pure, fresh air indoors and out, and not coddle ourselves up on cold days, but go out for a brisk walk, or run, or have a good game. A celebrated general, who lived to be a very old man, once told a well-known London physician that he considered he owed his health to the fact that he had never stayed indoors any day of his life because of the weather; he had never been afraid of fresh air.

Now, we will imagine we are examining a breath of air as it goes into the lungs, and in order to avoid fractions we will divide it up into ten thousand parts, and then we will do the same for a breath as it comes out of the lungs, and put the figures side by side on the blackboard, so that we can see the difference.

Breathed-in Air.		*Breathed-out Air.*	
Nitrogen	7,900	Nitrogen	7,900
Oxygen	2,096	Oxygen	1,630
Carbon dioxide	4	Carbon dioxide	470
	10,000		10,000

So we see that in breathed-out air the oxygen has been reduced about a fifth, and the carbon dioxide increased more than a hundred times. No wonder it is bad for us to breathe air which has been in other people's lungs, as we often do in stuffy rooms!

Now I will put on the blackboard the things we have learnt:—

1. People who breathe through their noses get the air well warmed and purified before it reaches the lungs.

2. Mouth-breathers are very apt to have lung diseases. Nose-breathers are much healthier.

3. Breathed-out air is warm and moist; it contains less oxygen and a great deal of carbon dioxide, which is a poison.

4. People who coddle themselves and are afraid of fresh air are apt to be pale and pasty-faced and easily get tired and fall ill.

5. Fresh air and brisk exercise make big lungs, clear heads, rosy cheeks, and cheerful minds.

CHAPTER XII.

THE SKIN.

Necessary Apparatus.

Large diagram of the skin, either printed and coloured, or simply drawn on the blackboard.
Large glass jar.
Cloth.

Also, if possible—

Microscope.
Microscope slide of section of the skin.
Hand lens.

Accessory Apparatus.

Mounted specimens of different parasites, for microscopical examination.

Note.—Before commencing the lesson, slip the glass jar on to the hand of a child, and fill in the space between the wrist and jar by pushing a cloth firmly into this space all round, but not so tightly as to stop the circulation.

HAVE any of you ever seen a snake? Perhaps, if you have not seen a live snake, you have seen a snake's skin, for a snake has the power of casting off its old outer skin as you would cast off a coat, and of coming out in a fresh new skin which has been growing underneath the old one.

We do not cast our skins off all at once as the snake does, yet we are always changing: let us see how we do it, and so find out something about the use that the skin is to us. Sometimes we hear people say that we have seven skins. That is not true, for we really have two skins—or rather, one skin divided into two layers or coats. The lower one is the true skin or *dermis*, and the upper one is the scarf skin (*epidermis*). The dermis, or true skin, rests upon a layer of fat, which in its turn rests over the muscles (flesh) and fills up the spaces between them, giving a smooth, rounded appearance to the body. You remember that the muscles have each of them its sheath, or membrane; the skin is loosely bound to these membranes by delicate tissue called "connective tissue," because it is found in all parts of the body *connecting* various things together. The skin is also loosely attached to the upper surface of parts of the bones. Pinch up a piece of skin from the back of your hand. See! It is only loosely bound to

the parts underneath. The healthy skin is firm and elastic, and keeps a firm, even pressure on the blood-vessels underneath, preventing them from over-stretching; it is very important for that reason alone to keep it in good condition. The skin also acts as a protection to all the soft tissues lying below it.

Here is a picture of our skin. The lower part or dermis is made of a strong feltwork of elastic and fibrous tissue into which the original cells have altered themselves. You can see where it joins the upper skin or epidermis. Look along the line. Is it a smooth, even line? No. What is it like? Like a line of little hills and valleys, and the hills push up into the top skin, and the top skin pushes down into the valleys. These hills and valleys are therefore covered by the top skin, and the top skin is made up entirely of cells. The lowest rows are made up of long column-shaped cells, growing very actively, because they get plenty of food and fresh air from the tiny little capillary vessels in the true skin immediately below them. The lower ones reproduce themselves by dividing in two as they grow, and the lower halves, being nearer the blood, get the most nourishment, and in growing push up against the row above, from which they have split off. This upper row, therefore, becomes a little crushed and it also gets less food, for the lower one takes all it wants first. The further away the rows are from the blood supply, the more dried up and flattened do they get. The top rows develop a certain horniness which helps to protect the softer cells below: this layer is called the horny (corneous) layer. The uppermost cells are quite dry and dead, they have no nucleus, and are always being rubbed off by the friction of our clothes against them and by washing. Perhaps sometimes, when you have been taking off a dark stocking, you have noticed a little white powder on it. That powder is

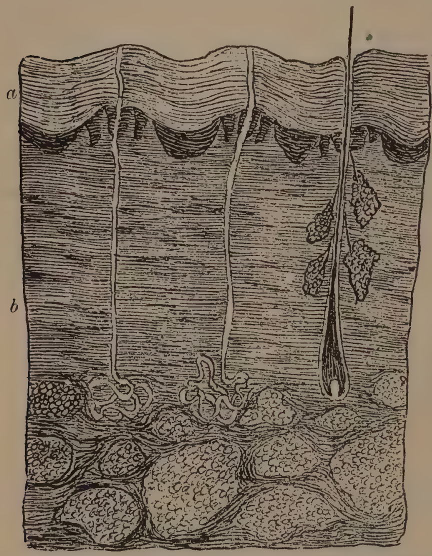


FIG. 47.—Diagram of Skin, showing Sweat and Sebaceous Glands. The latter are showing opening into a hair follicle.
a, Epidermis. *b*, Dermis.

really the dead cells of your skin. You can see them because, although they are so tiny that, when separated, we need a microscope to look at

Fig. 48.—Vertical section of Skin, much magnified, with a Hair follicle and Sebaceous Gland.

T, sebaceous gland. K, sweat gland. *b*, epidermis (horny layer). *d* and *f*, cells in lower portion of epidermis. *p*, hair follicle. *k*, hair emerging from skin. *a*, fat cells.

them, yet this fine dust is made up of quantities of them clinging together. We can put some in a drop of distilled water under the

microscope and see for ourselves, and we can look at a little piece of skin, properly mounted and stained as a microscope slide, and we shall see the true skin and the scarf skin quite plainly.

When we use one part of our hands a great deal, in doing hard work, does any change take place? Yes, the upper skin thickens, and becomes hard and horny, and so prevents the soft under skin from being injured. The uppermost part of the skin has no blood-vessels or nerves, so that it neither bleeds nor feels. That seems strange to you, does it not? You know how a tiny prick hurts you and how quite a slight scratch can bleed. That is because the upper part is usually very thin indeed, although under the microscope it looks quite thick and has several rows of cells in its thickness. Yet so thin is it that we soon tear through it with a pin or cut through it with a knife, and so press on and hurt the nerve-endings which are in the true skin, and we also injure the blood-vessels. But if the upper part of the skin has got very thick, it can be cut into with a knife and no pain is felt. A person with very horny hands can even pick up a hot coal and not feel any inconvenience. If people wear badly fitting boots and shoes, which press or rub on the foot, the skin thickens and forms what is called a corn, and this corn presses down and hurts the nerve-endings in the soft skin below. If the upper skin is much injured by some irritation, perhaps a burn, then the blood-vessels beneath get injured too, and lymph pours out under the upper skin and raises it, forming what we call a blister. It is not water which is in the blister, although it

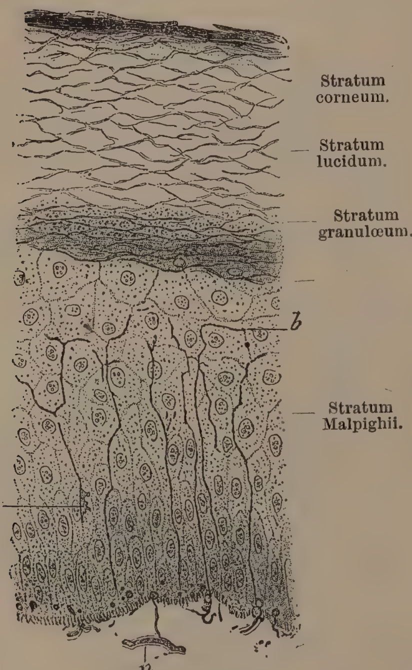


Fig. 49.—Vertical section of Human Epidermis, showing fine nerve fibrils branching into lower portion among the active cells.

n and *b*, nerve fibrils.

looks so much like it. It is the nourishing part of the blood. If you want to let it out, be sure you use only a very clean needle to prick it with, *never* a pin, or else snip it with a *very* clean pair of scissors. Really, it is best to put your needle or scissors into some disinfectant before you use them, or to pass them through the flame of a spirit-lamp, which will burn up any germs without making the needle or the scissors black, as an ordinary flame will always do. But if we cannot do that, at least we can be careful to use only something we have cleaned thoroughly, and never anything at all rusty.

Now look carefully at the skin of your finger-tips. What do you see? Little lines and ridges, forming patterns; they are never alike in anyone, and, however people may alter in other ways, these lines always remain the same, and therefore, by taking impressions of the finger-prints of thieves and other criminals, these persons can always be recognised again later on, however carefully they may have disguised themselves.

The true skin is well supplied with blood-vessels, and contains many things. In it are the ends of the nerves, fine threads which run all over the body, and carry messages to and from the brain and spinal cord. We shall learn much more about them later on. It also contains a vast quantity of little tubes, called sweat or perspiration glands (fig. 48, K). These glands are a quarter of an inch long if unwound, but they are coiled up into little balls in the skin, and one end works its way up like a corkscrew, as you see in the diagram, and opens on the surface of the scarf skin. With a hand lens you can see the little openings quite plainly. These are the pores of the skin. The little coiled-up gland is covered up by a network of blood-vessels, and the sweat glands, which being tubes are called "tubular" glands, have walls made of cells which have formed themselves into little tubes to carry off waste matters, and especially water, from the blood, and they do a very great work. If you were to take a piece of skin from the palm of the hand, measuring an inch square, and were to put it under a microscope and count the openings of the sweat-glands, you would find out that there were three thousand of them. As each tube is a quarter of an inch long when uncoiled, you can do the sum and find out how many feet of tubing there are in that one square inch. There are a great many openings on the palms of the hands and the soles of the feet, and very few between the shoulders; but it has been calculated that if all the tubes in the body were uncoiled and put end to end they would form a tube at least ten miles long. Ten miles of tubing, all made of cells, busy purifying the blood! What harm must be done if anything stops the work, and how careful we ought to be to keep our skins clean and active so that they can get rid of the waste

matter and water, and so help the lungs and kidneys, which like the skin are busy purifying the blood!

Here is a big glass jar, which I put some time ago on the hand of one of you, and made her keep her hand in it a long time, and I stuffed up the space between her wrist and the neck of the jar with a cloth, so that the air did not get changed, and I told her to keep the jar cool if she could. Now we will take it off. Do you remember that I showed you how clean and dry it was before I put it on? Do you see any difference now? Yes, the sides of the glass inside are quite misty and damp. Where has that damp come from? From the blood. What got it out? The work of the sweat-glands. What is this moisture? Perspiration or sweat. As a rule you would know nothing about it, because the warmth of your body would be enough to dry it off into invisible vapour as soon as it was formed, and that kind of perspiration which we cannot feel is called "insensible perspiration." If we are doing hard work or it is hot weather, we may bring so much blood to the skin that more perspiration is made by the work of the sweat-glands than can be dried off at once, and then we feel it, for it collects in drops and is called "sensible perspiration." *Sensible* is a word which we get from the Latin, and means "that which can be felt," though when we talk of a "sensible" person we use it in a different way. In the drying off of the sweat and its passing into vapour a certain amount of heat is used up, and that heat passes into the vapour and out of the blood, and so the blood is kept from getting above a certain temperature. This is very necessary, for the food we eat is like coal in a fire, always making heat, and if we did not have some way of keeping the blood cool we should reach boiling-point in less than two days! But the skin is a wonderful heat-regulator, if it is not interfered with. If the air round us is hot, the nerves in the skin feel it and let the brain know, and the cells of the brain send out telegraphic messages down the nerves and blood comes hurrying along to the skin in greater quantities, and the sweat-glands are able to take out more water and send it up to the surface of the skin, and, as it dries off, it cools the skin and the blood underneath it. That is why it is so dangerous to run about and get very hot and perspiring and then go and sit in a draught, especially if we are wearing the kind of clothes that do not suck up moisture, but let the water stay on the skin; for draughts of air help to dry up the perspiration in great quantities very quickly, and to chill the blood; and so, perhaps, we catch a bad cold. If it is very cold weather the skin is not so active, for the citizen cells in the body say, "We must keep the blood warm to-day, it must stay below." If, however, we run about or take a brisk walk, we feel and are warmer, for exercise makes us warmer, and also the warm blood

coming up to the skin is felt by the nerve-endings. It is very wholesome and good for the skin if we take exercise in cold weather, for it gets better nourished than if we sat still and shivered with cold; and what is good for the skin is, in this case, good for the whole body.

Besides the sweat-glands, the skin is full of little bag-like glands with narrow openings (fig. 48, T). They hold a kind of delicate, oily matter which keeps the skin soft and supple. It is called sebum, and the glands themselves are called sebaceous glands. Sometimes these little glands get choked up with too much sebum, and then, being greasy, the top gets coated with dirt and forms what looks like a little black speck and is called by some people a "blackhead." The little gland can be emptied by squeezing, or by pressing a watch-key down over it. Do not use strong, coarse soap for the delicate skin of the face. Very cheap, highly-coloured, strongly-scented soaps are usually bad for the skin; they are so strong that they take away too much of the natural oil and make the skin liable to crack and chap. One of the best things for the skin is inside and outside cleanliness. If people do not every day get rid of the rubbish of what they eat, it creates poisons in the body, which make the skin dull and bad-coloured. Want of exercise also helps to spoil the skin, for the blood does not circulate enough in it and so cannot carry away impurities properly or bring enough fresh air and food. Outside the body we should use plenty of clean water and good soap. Soft water is best for the skin; it is better than many of the expensive things that some people waste a good deal of money over. Powders and pastes choke up the pores. Dirty, neglected skins get a kind of crust over them, and in this crust germs can grow. The crust is made up of dead scales of skin pasted together by the skin's natural grease, and mixed with salts from dried perspiration and with dirt and dust from the air. Salt will hold moisture, and if left on the skin keeps it cold, clammy, and unwholesome. People who neglect their skins are liable to skin diseases and to other diseases as well. Dirt means germs. Dirt also sometimes means other things as well as germs, for people who have dirty skins and dirty clothes are often infested by disgusting insects. Insects which live on living creatures such as animals and man are known as "parasites." People with clean skins, clean hair, and clean clothes do not suffer from them. Always, wherever you may be, try to keep yourself clean and so keep your self-respect. Keep your skin active by healthy exercise and fresh air! Remember the skin has a lot to do to purify the blood. A hot bath once a week for cleansing purposes is good, but a daily tub should also be taken in warm or quite cold water; or, if this is a difficulty, then a brisk sponge down, or even a rub with a damp, rough towel and a brisk rubbing with a dry towel

afterwards, will go a long way as a substitute for a proper bath. This is very good for the health; it cleanses the skin, keeps the pores free from dead scales, dust, and germs, brings the blood up to the surface, and so nourishes the whole tissue.

Very hot baths are not good for ordinary use, and as a rule should be taken very quickly, as they are weakening, and also not very safe for people who may happen to have weak hearts. The warm bath, which can be taken constantly, is a great cleanser and refresher. The cold bath is, for those who can take it, one of the finest possible tonics, but it is not a bath in which, except in very mild weather, people ought to stop and soap themselves. The cold bath should always be taken quickly; there should be no standing about and shivering while we are trying to be brave enough to get in. It is best to have the bath prepared overnight so that there need be no waiting in the morning. The sponge should be a good large one; it is no use trying to have a good cold bath with a sponge the size of a threepenny-bit. Jump in, fill the sponge, and souse the water over you as quickly as you can. Remember that it is not playing the game if you curve your backbone so much that the water simply pours out of the squeezed sponge at the back of the neck and falls straight down into the bath. Half the good of a cold bath is lost if the sponging of the backbone is shirked. The first effect of the cold water is that the person taking it catches his breath; then the little blood-vessels of the skin contract and drive the blood inwards; next deep breaths are taken, the blood comes rushing back to the skin in a warm glow, the circulation of the blood is powerfully stimulated, every organ in the body benefits by it, and, though the bath itself may only last a few seconds, the reaction from it may last for many hours. The cold bath is a splendid nerve tonic, but it should never be taken by people who do not get a good reaction afterwards; that is to say, if after the bath there is no glow of warmth, if the person feels cold and shivery, then the bath is not good for him. No one with bad circulation should take cold baths, nor should they be taken by people with weak hearts. A bath with the chill just off can, however, often be taken and give a good reaction, and its temperature should be just a little lower than the temperature of the blood, which is 98·4° Fahrenheit. A bath at a temperature of 60° will often give a fine reaction and do a great deal of good, when an icy cold one might do a great deal of harm. After jumping out of the cold bath there should be a brisk rubbing dry with a rough towel, and the whole skin should glow with a delicious feeling of warmth and healthy life.

We shall talk about the question of clothes separately, but we may remember now, while we are talking about the cleanliness of the body, that we should always be most particular about those clothes which are

worn next the skin, for into them go the waste matters of which the skin gets rid, and therefore they need to be the most often changed of any.

The skin on the hands is particularly likely to get dirty and to collect germs. We should never so far forget the respect due to ourselves as to go about with dirty skins one moment longer than is absolutely necessary; and it looks particularly bad to see neglected hands. If we work we naturally dirty our hands, but we need not keep them dirty after we have finished our work. Our nails, too, need special care. Nails are formed from the skin and grow in a groove called the nail-bed. The skin at the edge of the nail near its root is rather apt to grow over the white half-moon part of the nail, but it should be pushed down when the hand is moist after washing, and so be kept from hiding the half-moon and also from becoming ragged and untidy. The nails themselves should be carefully trimmed, and never bitten, and should be kept scrupulously clean. Nothing looks worse than dirty hands and ragged, black, and neglected nails. Hands also should always be washed regularly before a meal. If people always did this, not only would it be a refined and civilised thing to do, but it would prevent a good many illnesses.

Besides the skin, there are other important organs which purify the blood. They are the kidneys, and they are two in number. Their position is in that cavity or hollow of the body below the diaphragm which is called the belly or abdomen. They are placed one on each side of the backbone, between the eleventh rib and the highest part of the haunch or pelvis bones. The great organ called the liver is just above the right kidney, and the organ called the spleen above the left. Both kidneys lie close against the back of the hollow of the abdomen, so that the food-tube is in front of them. Here is a picture of a human kidney (fig. 50), and here is an actual sheep's kidney. You can see that they are very much alike, the shape being quite the same. They have a great deal of work to do to help the skin to purify the blood, and they are very much like the skin in the way they are made, for the skin, as we have learnt, has "sweat-glands" like fine tubes, curled up into balls below, and opening on the surface of the skin and pouring out water and some salts from the blood. The kidneys also are full of little tubes; only, they begin on the outside instead of on the inside, and they run down inside the kidney and open into a little empty space at the inner side of it (fig. 50, P), and take water and salts from the blood and send both away down long tubes, one of which comes from each kidney, and these tubes in their turn open into a reservoir called the bladder, from which the waste matters are finally expelled. The special salt which these organs take out of the blood is a very important

waste matter, and represents what is left of the kind of food called nitrogenous food, after the coarser parts have been got rid of through the work of the intestines, and the nourishing digested part, having

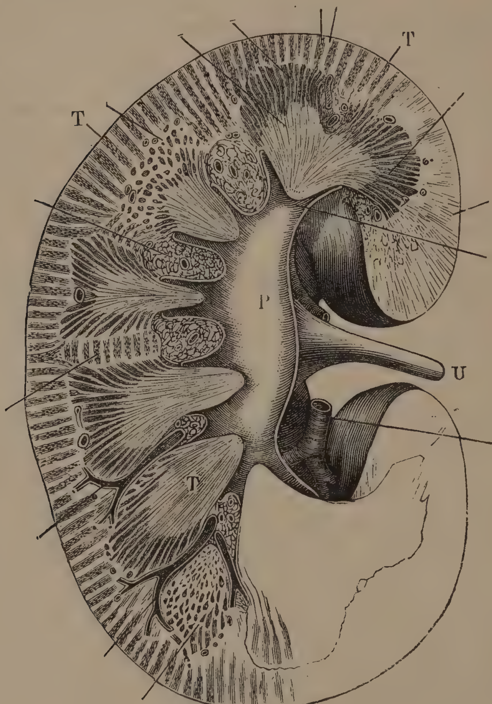


Fig. 50.—Section of Kidney.

P, pelvis or basin of kidney. U, ureter or tube carrying away waste matter to bladder. T, bundles of urinary tubes opening into pelvis.

passed through the walls of the intestines and got into the blood, has been used by the various citizen cells to which the blood-stream has carried it. These foods contain the element nitrogen, about which we have already learnt so much. You remember that the plants get it out of the air for us and build it up into foods that men and animals can eat. When those foods have been digested, and the good that is in them has passed into the blood and been carried to the cells, the cells

use it and burn it up much in the same way as coal is burnt in a fire, and in the same way as they burn up the fat and the sugar which is brought to them also by the blood, or store part of it up for future use. Do you remember that when the carbon of the sugar joins on to the oxygen and produces heat or energy, a waste matter is formed? That waste matter is a gas whose name we learnt as carbon dioxide. We learnt that the veins carry it away from the cells to the lungs, and the lungs cast it out into the air, and then that the plants use it up again to form more sugar, or more fatty or oily matters. The same sort of thing happens with proteid or nitrogenous food when it enters the blood. It comes to the cells and builds them up, and the waste part of it, after it has joined on to oxygen, is this salt about which we have been speaking. Its name is urea, and, as we now know, the blood carries it to the kidneys, which take it and water out of the blood-stream as it passes through these organs, and finally it is got rid of. So you see that three organs, the lungs, the kidneys, and the skin, are the great purifiers of the blood, and get rid of water, gas, and salts, the waste matters which are no longer wanted.

Let us see now what we have learnt about the skin:—

1. The skin is divided into two parts: the upper one is the scarf skin (epidermis), the lower one is the true skin (dermis).
2. The scarf skin is made up of cells; it has no blood-vessels or nerves, and it cannot feel pain or bleed.
3. The true skin has blood-vessels, nerves, and glands. It is protected by the scarf skin.
4. The skin does three things:
    (*a*) It protects the tissues lying under it.
    (*b*) It purifies the blood by means of the sweat glands.
    (*c*) It regulates the temperature of the blood.
5. Dirty skins often lead to skin diseases, fevers, and vermin
6. Clean skins are good for health.
7. The kidneys help the skin to purify the blood.

CHAPTER XIII.

TEETH, AND HOW TO TAKE CARE OF THEM.

How many teeth have you got? You don't know? Some of you have lost a good many and are cutting your second ones. Before you began to lose any first teeth or cut any second, you had twenty teeth, ten in the top jaw and ten in the bottom jaw. Some of you have baby brothers and sisters at home who are cutting their first teeth, and very troublesome some of them seem to find it. Are the teeth all alike? No; some are "double teeth," with broad tops to them, some have pointed tops, some have sharp cutting edges. What does that show us? It shows us that our teeth are meant to do different kinds of work and bite different kinds of food. What kind of work do the broad-topped teeth do and where are they in the mouth? They are behind the other teeth, and the work they do is to grind, just as you can grind corn between two millstones. We call these teeth *grinders*. The other name for them is *molar*, which means *like a millstone*. It is a great pity to lose any of these teeth, because then we cannot grind our food so well and therefore the poor stomach has very hard work to digest it. Little children have only two grinders on each side in each jaw, eight in all in the mouth; but when they get to be six years old and have to grind more food, another molar or grinder appears on each side behind all the other teeth, four in all, so then they have twelve grinders. How many pointed teeth have you got? Two in each jaw, four in all. What are they called? Dog-teeth, or sometimes *canine teeth*, which means the same as dog-teeth. What is their special work? They hold on and tear. But human beings have not got to hold on to their food and tear it apart as animals do, so our dog-teeth are not nearly so sharp and long as theirs are. Look at a dog's teeth and notice the difference. Lions and tigers have tremendous tearing teeth. The two top canines are also sometimes called eye-teeth, because they have long roots which run up in the direction of the eye, and people used to think they were closely connected. Now we come to the teeth with sharp edges. What work have these got to do? They bite off or cut, because they have a sharp cutting edge. They are called *incisor* teeth, from a Latin word which

means to cut. How many have we of them? Four in each jaw, eight in all. Let us see now if we have learnt how many teeth little children have before they are six years old. I will put it on the blackboard, as you tell me.

8 molars or grinders, 2 on each side, 4 in each jaw.
8 incisors or cutters, 2 on each side, 4 in each jaw.
4 canines or tearers, 1 on each side, 2 in each jaw.

---

20 first teeth in all.

Now suppose I put it in another way. I will draw a long line first. This shows the division between the upper jaw and the lower jaw. Next I will draw a short line across it. This shows an imaginary line drawn between your four front teeth, upper and lower. Now we will write down on each side how many different kinds of teeth we have when we are tiny children. I will begin from your top right-hand jaw and so across, and then take the bottom jaw.

Molars.	Canine.	Incisors.	Incisors.	Canine.	Molars.		
2	1	2	2	1	2	=10	=20.
2	1	2	2	1	2	=10	

Note.—Except in the Infant Schools, all the children will have at least three molars on each side, unless the first ones have gone and the second are not yet cut.

Now you are losing your teeth and getting others, and some of you have already got three, or even four, big back teeth on each side. In the second teeth the first two grinders next to the cutting teeth are called bicuspids as well, because they have two little cusps or points on them, and *bi* means two. You cut your first bicuspid of the second set when you are about nine and your second when you are about ten. You cut your second set of canines at about twelve years old. Your first grinder of the second set comes at six years old, behind the first teeth; but the second one doesn't come till you are fourteen; and the third usually comes between the ages of seventeen and twenty-five, but it may come much later, or even not at all. These four last teeth are called the *wisdom teeth*, because you are supposed to be wise by the time you get them. Cutting teeth are changed at about seven to eight years of age.

Now we will put on the blackboard how many teeth a grown person gets in all.

Grinders.						Grinders.			
Molars.	Bicuspids.	Canine.	Incisors.	Incisors.	Canine.	Bicuspids.	Molars.		
3	2	1	2	2	1	2	3	=16	=32.
3	2	1	2	2	1	2	3	=16	

Have first teeth any roots? Perhaps you think they have not, because they come off without any. But if you look at this diagram (fig. 51) you will see that they all have roots, and, moreover, that these roots are touching other teeth deeply buried in the jaw. These are the second teeth waiting to come out, and the blood uses up the roots of the first teeth in order to build the second teeth. When it has used the root quite up, the first tooth gets loose and drops off, and the second tooth pushes out into its place. If we let our first teeth decay, we shall do harm to our second teeth, so we must take care of our teeth from the very beginning. A little new-born baby has got its first

Fig. 51.—Lower Jaw of Child five years old, with surface removed to show Permanent Tooth Germs.

teeth in its jaw waiting to come out, and it has got the beginnings of its second teeth too, and if it does not get the right kind of food its teeth will not harden and cut properly. A baby wants plenty of clean, good, nourishing food which it can digest. It cannot digest some foods at all, and if it is fed on them it usually becomes fretful and ill, and the food does not make good strong teeth. Little babies under six months old ought usually to have nothing but milk, for that is what they can digest, and milk makes good teeth.

This is how a tooth is made. The part which comes above the gum is called the "crown" of the tooth. This crown is covered with enamel, the hardest thing in the body. Inside that is "dentine" or ivory, and inside that again is the pulp, which is full of blood-vessels and nerves. How do the blood-vessels and nerves get in? Here is a picture which will show you (fig. 52).

The artery and nerve get in through a tiny opening at the end of the root of the tooth. The artery brings fresh air for the different

little cell divisions and also food for their nourishment. Bicuspids have two fangs, and molars have four, and each fang has its own little blood-vessels and nerve-branch coming in. The nerve comes in from the brain, so if our teeth ache we often feel the pain in our heads as well. A little vein carries away the impurities, and so do some other vessels called *lymphatics* which are in the neck. These lymphatics go through enlargements of them called glands, and if we have decayed teeth these glands often become swollen and painful in their effort to get rid of the poisonous matter. The enamel is a great protection to the

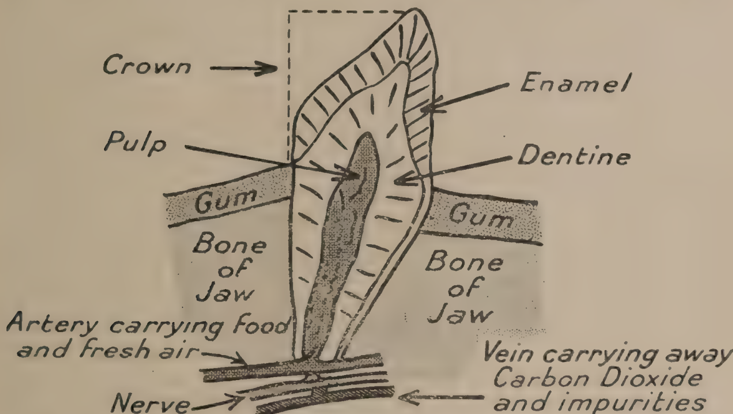


FIG. 52.--Parts of a Tooth, showing how it gets its food and fresh air.

teeth, and good teeth are very important to health, so we ought to learn how to take care of them and how to use them properly. We must take care to bite our food well before we swallow it, for we shall digest it so much better if we chew it well and mix it up with the water in the mouth, which helps to digest it. "Bolting" food down, without biting it properly, is very bad for the digestion. When children are two years old they ought to have solid food only at meal-times, when they can bite it well, and they should be allowed to digest one meal before another is given. Very soft food is not good for children; it gets them into the bad habit of "bolting" their food. Whole-meal bread, bread made from "seconds" flour, is far better for the teeth than fine white bread, which is very bad for them. Whole-meal bread has bran in it, and this keeps the teeth clean, but fine, white flour sticks to teeth and causes them to decay. Whole-meal bread needs more

biting, and that means that the healthy saliva flows out more abundantly; and as it begins the digestion of the starchy part of the bread, it helps the other digestive organs very much. Healthy saliva helps very much to keep teeth healthy. If we eat crusts and hard things, we have to grind well, and that brings more blood rushing along the little artery, and so the living cells of the teeth—the citizens of the teeth—get more fresh air and food than ever, and so grow strong and healthy. We eat such soft food nowadays that we ought to try to remember this, and also when we brush our teeth we ought to brush the gums as well, to bring more blood to them and nourish the roots of the teeth. If they bleed a little at first it won't hurt us a bit—it only shows us what stupid, soft gums we have got; and if we go on every day brushing them a little when we brush our teeth, they will soon be firm and pink and healthy and will never bleed again.

Why do teeth decay? Partly because we neglect them, partly because we may be born with rather weak enamel, but principally because we do not take care of them properly, and because we allow germs to attack them. These germs, or bacteria, as we ought to call them, are very tiny, invisible little things. They are very humble plants, and they do a great deal of good in their proper place, but their proper place is not in our mouths. They get in with the food we eat, the air we breathe, and the water we drink, but there are never very many in clean, well-cared-for mouths, for they get nothing to live upon. But if people neglect their mouths and also eat soft foods, the germs find plenty to grow upon in the little coating of starchy and sugary matter that covers the teeth. As they grow they form acids out of the starch and out of the sugar, and these acids dissolve the hard lime-salts out of the enamel of the teeth and soften it, and then the germs get in and attack and destroy the ivory and form a little hole full of poisonous decaying matter. Every decaying tooth is a little ulcer, and the nearer the decay gets to the pulp the greater is the pain. Sometimes the decay gets right down to the very end of the root and an abscess forms and causes intense pain. Sometimes the matter makes the glands swell up and the person ill and feverish; sometimes it escapes up round the tooth or through a gumboil into the mouth; but in every case poisonous matter is being swallowed, the breath is bad, and people are often pale and ill. Nobody can be really healthy and well who has bad teeth, and they ought to be attended to directly the decay begins. It is a great pity to let teeth decay until they ache and then have them pulled out. What can we do to save our teeth and keep our mouths clean and pure? First we can try to eat plenty of hard food as well as soft food—but we must not crack hard nuts with our teeth. Then we must wash our teeth carefully, so as not to leave anything sticking *to*

them or any little bits of food sticking *between* them for the germs to grow on. It is very important to wash them at night, for, if we do not, then the germs have the long hours of night to work in. Let us try to be sure to wash them night and morning. Very careful people wash them after every meal, but that is a very difficult thing to do sometimes; but everybody can wash them night and morning, and no one is too poor to afford a tooth-brush, for you can buy them very cheaply nowadays, and it is a horrid idea to have a neglected mouth. Brush the teeth not only backwards and forwards but downwards and upwards beginning from near the gum. That is nature's way of cleaning teeth. Be sure you brush them on all sides—the backs need brushing quite as much as the fronts. Remember always that self-respecting people don't do things "all for show," and think of that when you brush your teeth as well as when you do other things. Brush the *tops* of all the back teeth, for germs and food often collect in the little puckers. Use plenty of clean, fresh water and for powder or paste there is nothing cheaper or better than a little precipitated chalk—if you get it "camphorated" it is rather nicer. Twopennyworth of camphorated chalk will last a long while. It is a good plan when you have dipped your brush in the water to rub it on a cake of pure white soap before you dip it into the powder. This will keep your teeth beautifully clean, and will do a very great deal to prevent them decaying even if they are naturally delicate.

Now we will write on the blackboard some of the things we have learnt:—

1. Hard foods, well chewed,
   Help to make and keep teeth good.
2. Soft foods coat the teeth, but hard foods clean them.
3. Eat slowly, chew thoroughly.
4. A clean mouth makes a sweet breath.
5. Food left on or between the teeth brings decay.
6. Unclean teeth decay mostly during the night.
7. Clean the teeth just before going to bed and again in the morning.
8. Use a small tooth-brush with stiff bristles, a little white soap, and some precipitated chalk.
9. Brush all teeth thoroughly, especially the back ones. Brush all the surfaces, not only the front.
10. PROPERLY CLEANED TEETH SELDOM DECAY.

CHAPTER XIV.

THE NERVOUS SYSTEM.

Necessary Apparatus.

2 lbs. of modelling clay. *N.B.*—The clay must be kept in a damp cloth, or it will harden and become useless. Putty will also do, but it is disagreeable to handle. Plasticine might be difficult to obtain in such a quantity.

Two pieces of paper, one double the size of the other.

Diagrams of central nervous system.

Accessory Apparatus.

Microscope.

Anatomical slides of nerve cells and nerves and sections of the spinal cord.

Note.—This lesson being very long will need much subdivision. It can be taken without the lesson on dissection which follows it, if so desired. If practical demonstration is wished for, it is an easy matter to obtain the fresh spinal cord of an ox and cut it across to show the structure, which, however, will not be very evident without staining. The nerve roots can be demonstrated.

The modelling of the brain described in this chapter is adapted from Dr Leonard Hill's *Manual of Human Physiology.*

We found out long ago that the tiny little one-celled amœba has in a simple form the powers of life which run through the whole of creation. We have been talking about the power of *assimilation*—that is, of *making like*; we have learnt how the living cell can take in dead matter as food, digest it, and make the digested food like the living protoplasm of its own body. We have seen how this power is carried on in a much more complicated way in our own bodies. But now we want to remember how it is that the animal *knows* where its food is and is able to get it. It finds this out through that other great power of life, the power of *response to a stimulus*, or, in another way of putting it, the power of *irritability*. Protoplasm will respond to several kinds of stimulus. If you put your finger on a hot stove, you draw it away quickly and you feel pain. You have responded to the stimulus of heat. If you look at the sun, you blink your eyes. What have they responded to? The stimulus of light. Can you think of any other things? A splash of cold water makes you shiver, a pinch of snuff makes you sneeze, the

smell of nice food may make your mouth water, an electric shock will make your muscles contract, the prick of a pin will make you start, a strong acid will burn and hurt you and make you shrink from it. All these are different kinds of stimuli, and ones you know about, or are *conscious* of, as we say. There are many others to which we react or answer, but of which we are not conscious. We do not feel conscious of the stimulus which causes the glands in the stomach to pour out their digestive juices. We may, during sleep, move away from something which touches us and yet not know that we have done so. All these answers or reactions to stimulus can be traced back to their beginning in that power of irritability possessed by the simplest animals.

In many-celled creatures it was found convenient to have certain cells on the outside of the body specially for feeling, and they became very sensitive. What practically happened was, that in effect they said to the rest of the cells, "If you will protect us and see that we get fresh air and digested food, and will see that our rubbish is cleared away, we will act as scouts and keep on the look-out and tell you about the outside world." So these cells protected themselves behind the skin cells. They were so sensitive that they would have been hurt easily if they had always stayed on the outside. All the living cells of the body keep the power of answering to a stimulus, but these others make it their special business. They are known as *sensory* nerve-cells. In order to let other cells know what is happening, they send out delicate branches to touch the others and stimulate them, and one long fibre is sent down below to the cells inside. These sensory cells, close under the skin, feel if anything touches them, and if light, cold, heat, electricity, or chemicals are affecting them they send a message down to the body cells: "Look out! it is very cold," or "Look out! it is too hot," or "Look out! food

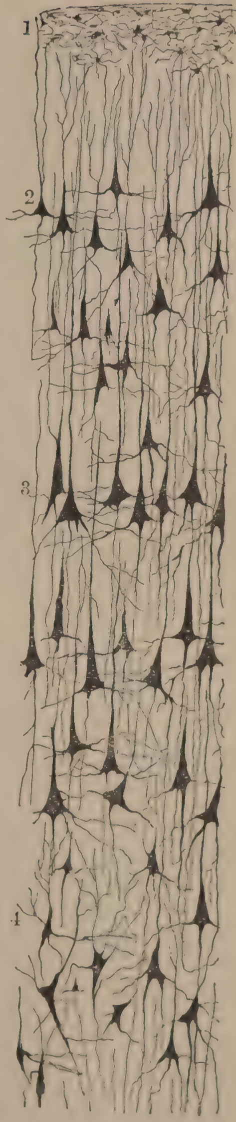


FIG. 53.—Section of Cerebral Convolution.

1, neuroglia layer. 2, layer of small cells. 3, layer of large pyramidal cells. 4, layer of irregular cells.

is coming." But it has been found a better arrangement to pass the message on to other special cells, who in their turn make it their particular business to pass the news on to the muscles and tell them to contract and move the body. These cells which give a stimulus to movement are called *motor* cells. The whole of the nervous system consists really of these two kinds of cells; the duty of the first, or sensory cell, being to receive the impression and pass it on to the second, or motor cell, whose duty it is to tell the body cells and cause *action* to be taken on the news received. It reminds us of the way an army gets information. The army sends out scouts, and places sentinels, and sends up aeroplanes, and the duty of these is to keep on the look-out, gather information, and send in messages at once if any immediate need arises. The message is sent to the officer in command, who is like the

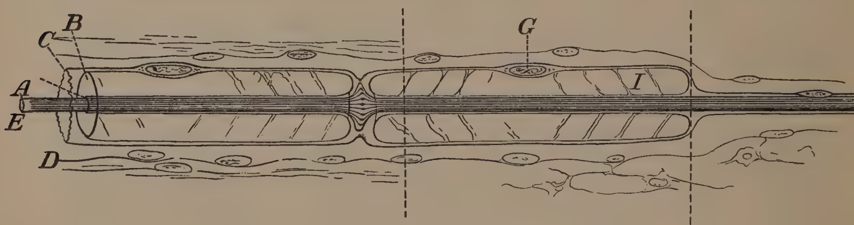


Fig. 54.—Diagram of Medullated Nerve Fibre.

A, axis cylinder. B, medullary sheath. C, sheath of Schwann. D, connective-tissue sheath. E, axis-cylinder sheath. G, nucleus.

motor cell, for he gives the orders to the troops and tells them what to do, and they move accordingly—just as the body acts when the motor cells stimulate the muscles. A scout with a telephone wire is very like a sensory cell with its long fibre.

Several of these fibres, coming from nerve cells, when joined together form a nerve; just as we know that many telegraph wires are carried on the telegraph poles. Some of the nerves have sheaths round them, and are called medullated nerve fibres. These sheaths are fatty, as they are made from fat cells which wrap round for a protection to the delicate nerve. Over the fatty covering there is a fine membrane. Lymph from the blood can soak through the divisions between the fat cells and nourish the central fibre or *axon*.

In the higher animals we find that the sensory cells under the skin have withdrawn further into the inside, leaving long threads and very sensitive ends near the surface. The long fibres from them go inwards to a whole mass of nerve cells and fibres, placed inside the backbone, and forming a long cord in its centre. This is known as the *spinal cord*.

This cord, made of nerve cells and their fibres, is most carefully protected. It is wrapped round with delicate membranes, and the bones of the spinal column grow round it to protect it. You remember that each separate bone has a central ring, and through this central ring passes the cord like the string in a row of beads. The upper end of this cord is enlarged into the great mass of nerve cells and nerve fibres known as the *brain*, and is enclosed in the bony box called the skull, which protects it. At intervals all down the backbone, between each separate bone, or vertebra, as we remember that they are called, nerves branch off. There are thirty-one pairs of them, and they each branch off by two roots which join together when they meet, forming one bigger trunk nerve. This nerve contains the fibres belonging to both the sensory and the motor cells, but the two roots contain them separately. The sensory fibres [1] are coming *in* to the spinal cord from the skin, but the motor fibres [2] are coming out, and are taking messages to the muscles as a result of the news brought in by the sensory fibres.

FIG. 55.—Brain and Spinal Cord, shown in position.

On each side of the backbone lie little clusters of nerve cells, joined to each other by fibres and looking rather like beads on a chain, with a certain distance between each bead. Such little masses of nerve cells are called ganglia (sing. *ganglion*). These ganglia are joined by a branch from each nerve as it comes out of the spinal cord, with the exception of the nerves in the back. They send fibres down to the digestive and other organs of the body. Some fibres go to the heart, some to the intestines, others to the spleen, others to the blood-vessels; and fibres

[1] Sensory nerve fibres are also called "afferent," from *ad*, "to," and *fero*, "I bring." They bring messages of sensation up *to* a centre.

[2] Motor nerve fibres are "efferent," from *ex*, "from," and *fero*, "I bring." They carry messages *out* from a centre.

from end-cells in these organs bring sensory messages up to the cells in the ganglia, telling of the condition of these organs and what their needs are. These chains of ganglia down each side of the spinal cord and the nerves from them are known as the *sympathetic nervous system.*

As these cells are in connection with cells in the spinal cord, and they again, by means of their fibres, are in connection with cells higher up, and the cells higher up are in connection with the part we call the brain, it is easy to realise that the whole nervous system might feel it if the organs were not acting properly. But, as a rule, messages from this system are not allowed to trouble the brain with their work, and after delivering their news to the motor cells in the lower centres they get bent back and do not reach the brain at all.

As an example of what we have been saying, let us suppose that food has been taken into the stomach. Its presence there stimulates nerve cells in the walls, these send a message up through the sympathetic nervous system to motor cells, and the motor cells send a message down to the blood-vessels in the walls of the stomach and make them enlarge. More blood comes to the walls, the cells of the glands get more food materials, and *instantly* pour out gastric juice to digest the food. An action like this is called a *reflex action*—it is done without the brain ordering it. The word reflex comes from the Latin, and means bent back, and we see that the stimulus is bent before part or all of it can reach the brain. If the food in the stomach is harmful, then it is possibly the case that the stimulus is so strong that it passes on from the sympathetic system to centres in the spinal cord, and the spinal cord may tell the brain, which is the part which feels and knows about things, and so perhaps we feel a pain and may have to take medicine to make it better. Pain is like an electric bell, warning us of danger.

The nervous actions connected with the mere fact of living are all reflex. We swallow our food by reflex action, we digest it, we blink our eyes at a bright light, we breathe by reflex action ; our skin perspires naturally and keeps the blood cool by reflex action ; and many other actions go on without our knowing very much about them and without our direct control. If a man has an injury in the cord, so that messages going up to the brain are interrupted, he may lose all power and feeling in the parts below the injury, and his legs will not move, however many messages may be sent down by cells in the brain, for they can get no further than the part where the cord is injured. On the other hand, the man may not be able to feel even if his foot is pinched, for the messages from it get no further than the same break. Nevertheless, reflex action may still take place. For instance, if the foot is tickled or pinched or hurt in any way, it will be jerked away by the action of motor cells in the spinal cord below the place of the injury, but he will

know nothing about it unless he *sees* it happen, and then the cells in the back of his eyes tell the brain.

Here is an example of reflex action which you can try for yourselves. Sit down and cross your knees, and let the upper leg swing freely. Then, with the side of your hand, or with a ruler, hit smartly just below the knee-cap and a little to the outer side. What happens? The foot jerks. Can you help its jerking? No, you cannot stop it from doing so unless you hold it. There are several reflexes in the body which a doctor sometimes tries in order to find out whether the nerves are acting properly.

At its top end the cord widens out into a thicker part, called the spinal bulb (medulla oblongata), which lies at the back of the head, just inside the skull. Here, as we have already learnt, are the cells which control the beating of the heart, the breathing of the lungs, and the size of the blood-vessels. Inside the skull we find that the cord has developed into a *brain*—that is to say, into a very large mass of nerve cells and fibres with higher powers than those of the spinal cord.

The brain is the organ of mind, and consists of the part known as the great brain (cerebrum) in front, and the little brain (cerebellum) behind, covering over the spinal bulb (see fig. 56). We will remember now that the brain and spinal cord form what is called the *central nervous system*, and that connected with it is the *sympathetic system* which controls the organs. Besides these, though really a part of them, are the nerves running to the outside (periphery) of the body and inwards from it, and talked of as the peripheral nervous system, but we need not trouble to remember this long name.

Now we will take this clay and make a rough model of the brain and spinal cord. First of all, I will roll a piece of clay to form a cord 20 inches long and as thick as my little finger. This piece at the end I will make as thick as my thumb for about 2 inches. Now I will divide this thick end into two for about the length of half an inch. Now we have a long cord with a thick end, and the end is divided into two sort of horns. We will call the thick end the top end, and the part of the cord which is underneath, and therefore touching the table, we will call the front surface. Do not get confused because the front is underneath; it is called the front because it represents the part of the cord which would be in front if it were a real cord and in the body. Now we will make four little balls of clay, about the size of very large peas, and put them on the back of the cord, close together just below the division of the top end. These little lumps represent masses of cells, and the part where they are found is called the mid-brain. The lower part of the thick end of the cord is the spinal bulb (medulla oblongata). Now I will take a lump of clay, about the size of a small

apple, and fix it on to the cord, just below the four little lumps. This represents the little brain or cerebellum, which you can see in the diagram (fig. 56). We will make a flat band of clay pass from one side of the little brain and go underneath the cord, which we will lift up a little, very gently. This band must come round and join on to the other side of the little brain. The band is mostly made up of fibres carrying news from one side of the little brain to the other. It is a bridge over which messages can pass (pons Varolii). The four little round masses

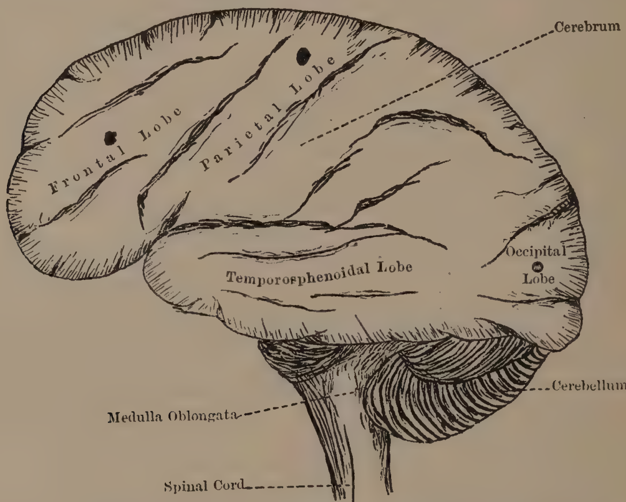


FIG. 56.—Showing Big Brain (Cerebrum), Little Brain (Cerebellum), Spinal Bulb (Medulla Oblongata), and Spinal Cord.

of cells which we put on before are called the fourfold bodies (corpora quadrigemina). We will make a cleft in the little brain behind, so as divide it into two. Each part is called a hemisphere. On the two short divided ends of the cord (peduncles of the cerebral hemispheres) we will put two small lumps of clay. These represent masses of cells lying underneath the big brain. Now we will take all the rest of the clay and divide it into two portions, and put one big oblong lump over one of these last little masses and the other lump over the second mass, and join them together underneath by a thin band of clay. This band represents a bridge of fibres by which the cells of one side of the big brain communicate with the other side (corpus callosum). These two big lumps are the hemispheres of the big brain or cerebrum.

There are other bands of fibres and other little masses of nerve cells connected with the brain, but I am not showing them to you now. Here, then, we have a rough model of the big brain, the little brain, the spinal bulb, and the spinal cord. The big and little brains are developed from the spinal cord. The little brain helps to control the movements of the body. The brain is so important that Nature takes great care of it. She makes it rest on a water-bed, to prevent shocks, she packs it round with three delicate membranes: one covers it closely (pia mater), another, as fine as a spider's web, is joined on to a tough, strong membrane which lines the inside of the bony box we call the skull, in which the brain is safely stored (arachnoid and dura mater). These membranes also enclose and protect the cord.

The surface of the big brain, for about the depth of a quarter of an inch, is composed of a grey matter which is made up of *cells*. In the spinal cord the grey cell matter is on the inside—just the opposite of the brain. This outside part of the brain is called the *cortex*. These cells on the surface of the brain send down their fibres, and as they pass downwards they form the white matter which is found in the centre of the organ. These fibres terminate round cells in other parts of the brain, and they, by means of their own fibres, send on the messages to others lower down. From these cells and from masses of grey matter in other parts branch off twelve pairs of nerves, which are known as the nerves of the brain, or as *cranial* nerves. Some of these nerves are bringing messages *in*, others are carrying messages *out*. From end cells in our eyes and ears, and in the skin of our head and face, and from our tongue and teeth, messages are streaming straight in to the brain itself, giving it impressions of the outer world. The eye cells give one sort of impression, and the ear cells another, and skin, and teeth, and tongue others again, and in the spinal bulb messages are coming in from heart, and lungs, and blood-vessels to motor and sensory cells in the brain. Some of the impressions do not ordinarily go higher than the spinal bulb, and we are not conscious that we have them, but the motor cells know, and they order the heart to beat and the lungs to breathe at the rate suitable for the information brought in. It is only if things get difficult to do that they send an urgent call on, by relays of cells and fibres, to the big brain, where *we feel and know*, for the big brain is the organ of *consciousness*.

We have already heard that the surface of the big brain is called the cortex, and that it is about a quarter of an inch thick and is made up of cells and their branches. This cortex is so important that Nature tries to get as much of it as she can, without having to make an enormous head to keep it in. Let us see how she manages it. Here is a square piece of paper, and here is another which is very much larger.

The smaller piece of paper just fits the lid of this box, and we will call it the cortex of the brain. There is no room for any more in the box, so long as it lies flat. But I will now take this second larger piece which is much too big to fit, and I will make pleats in it all across. Now it measures no more than the other from end to end, and it will fit into the box also; but as a matter of fact we know that its surface, if pulled straight again, would take up far too much room. Nature throws the surface of our brains into these crumples or pleats, which are called *convolutions*, and the more there are of them and the deeper they are, the greater amount of the wonderful grey cell matter on the surface does that brain possess. The brain in an idiot may have hardly any convolutions, or even be quite smooth. The brain in man weighs about 49 oz., and in woman 44 oz. The brains of some great men have weighed many ounces more, and some idiots have very small brains.

The big brain or cerebrum is, or should be, the master of the body; it is the noblest organ of all; it has the power of choice, of willing, thinking, reasoning, judging of the news brought to it. It has the power of storing up information and of using it later on. We call this the power of memory. The brain also has the power of saying "No," when perhaps the body badly wants to say "Yes," for the brain is influenced by its greater knowledge and by the memory of old experiences and impressions. If we put our hand into the fire by mistake, we snatch it away again at once, almost before the brain even knows of the pain of the burning heat, for the message of danger runs up from the branches and end-cells under the skin to the sensory cells of which they are a part; the sensory cell, safely hidden close to the spinal cord, having received the message of pain along its branch from the outside world, sends the message on by its other branch *inwards* to the motor cell in the cord itself; the little branches of the motor cells collect the message, and the cells send a message *out* to the muscles of the arm and hand, and the hand is snatched away. The fibres and branches of the sensory cells are in touch with cells higher up, and by their fibres they pass the message of pain on to the brain. Perhaps the brain says to the motor cells in the cord, "I forbid you to take the hand away"; the pain is great; the body cells try to disobey, but the brain may insist and the hand be badly burnt in the attempt to save someone else from the burning flames. The soldier may be wounded, worn, and suffering, and all the body cells be crying out for rest, but his higher knowledge tells him that a little further on may lie victory or safety, and he makes his weary body obey him. Deeds of courage and unselfishness are done by the higher and nobler parts of us refusing to listen too much to what the body wants. One of the most powerful things in life is the instinct of preserving it, and yet we are hearing every day of people

who are sacrificing their lives to save others and bearing pain cheerfully and bravely.

This power of the brain to choose and to rule is a very great power indeed. We are always receiving impressions from our bodies, and we owe our health and lives to obeying wisely the messages brought; but if we obeyed them all and did not judge, we should be little better than animals. If we want to be men and women and not mere creatures of impulse, we must stop and *think* before we do certain things. We can train our brains to obey the higher parts of our nature, the things which our conscience, our wisdom, our love, our religion, our memory tell us are right, and we can do these things, even if our bodies or our self-will or our bad tempers want to do the contrary. Unfortunately, we often see people who give way to their impulses and go from bad to worse. They want a drink, and they have it, though their wiser part may say, "You know it does you harm and you cannot afford it"; they want to lie in bed, and they lie in bed, no matter what they are neglecting; they want money, and they borrow it or perhaps even steal it; they are lazy, and they give way to laziness; they do not do the things that give them trouble, and in time they become a misery to themselves and to others. We have to learn to say "No," and that power of saying "No" is called the *power of inhibition*; and it is the great privilege of human beings to be able to think, and judge, and reason, and know when to say it. Fortunately, we do not have to stop and fight against temptation every time, for we get delivered from much temptation by getting into good habits. Good habits once formed are second nature, and the temptation resisted time after time at last dies out. Every time we do a thing we make it easier for the brain to do it again more readily and without having to think so much about it. This applies to good and bad habits alike, and to habits of the body as well as habits of the mind. The first time we try to ride a bicycle, we find it very difficult. We find that we have to think hard about it, and we grip the handle bars very tightly and keep our muscles on the strain in the attempt not to fall. But by and by we learn to ride steadily, and very soon we do not think of how we do it, for the central nervous system has become accustomed to the messages coming in from the arms and legs and the other parts of the body, and the spinal cord has learnt to give all the necessary answers without troubling the brain every time, so that now, as we ride along, we can admire the scenery and notice our friends as we pass them, for the spinal cord has set the brain at liberty. This power of making habits is very useful when the habit is a good one. We must try to get into the habit of being brave, the habit of being truthful, the habit of being kind and gentle to those weaker than ourselves—in fact,

all kinds of good habits. We never know when we may be called upon to decide something suddenly without time to think, and we want to feel sure that our habits are such that, in that moment, we shall instinctively do what is right without the loss of a second. Characters have been made and lost over and over again by the decision of what seemed a moment, but was very likely the result of years of trying to live up to the best, or, on the other hand, of years of selfishness and slackness.

How do the brain cells get their food and fresh air? The brain needs a great deal of both. The great arteries of the neck bring up supplies, and branches from them divide up into very fine vessels, and the delicate membrane next the brain is full of tiny blood-vessels; these going inwards break up into capillaries round the fibres and nerve cells, bringing each citizen its supply. The waste matters are carried away by veins which join to form the great jugular veins of the neck, and so the blood gets to the heart to be purified. It is very important that no poisons should reach the brain through the blood. If rubbish has not been regularly got rid of from the food-tube, then harmful matter may get in, and instead of the capillaries bringing only food and fresh air they will bring *a little poison* to the delicate nerve cells of the brain, and that poison may stupefy and deaden it, besides giving the person a headache. Many people make their poor brains work under difficulties by poisoning them with the bad air of stuffy rooms and with the poisons formed by eating or drinking too much and taking too little exercise. Strong drink may do terrible damage to the brain cells, and no child ought ever to touch wine or beer or spirits, because the developing cells are very easily damaged. Children have been stunted in growth and seriously injured in nerves and brain by having been made to drink strong drink. Cigarette-smoking also is so bad for growing boys that the law has stepped in and made it illegal for tobacconists to sell cigarettes to anyone under sixteen years of age. Two things which are bad for the brain (in addition to the poisons of drink, overeating, bad air, allowing rubbish to stay in the body, and want of open-air exercise) are (1) working it very hard *without* living a healthy life, and (2) letting it get stupid by *not working it enough.* Hard brain-work is good for us, so long as we lead healthy lives and do not worry.

The brain and nerves govern all the body, as we have seen. If they are out of order, then everything else is apt to get out of order too, for messages are not properly carried out. One of the most important things is *proper sleep.* During sleep the brain takes in stores of power to enable it to do its thinking and working, and builds these stores up out of the blood. During the day it uses up these powers. Wonderful

photographs have been made of brain cells, showing them when they are rested from sleep and full of power to do work, and also showing the tired brain cell, which has neither had sufficient sleep nor sufficient food. The growing brain is easily injured by want of sleep. Sleep ought to be taken early in the night. Growing boys and girls need ten to twelve hours of sleep. Very young children need even more, and a tiny baby sleeps eighteen hours out of the twenty-four, and needs them all. It is very bad for children to sit up late or to get up so early in the morning to do work that they are tired out before they come to school. Regular hours are good for children and grown people alike, but it is good for neither to lie in bed late in the morning, after they have had a good night's rest. The kind of heavy sleep they then get is actually harmful. Early to bed and early to rise is an excellent motto, and a very good habit for us all.

Blackboard Summary.

1. All the knowledge of what goes on inside and outside our bodies is brought to the brain and spinal cord by sensory nerve cells and their fibres.
2. All the work and movements of the body are carried on by orders from motor nerve cells and their fibres, after receiving news from sensory cells.
3. Sensory nerves bring messages from the skin to the spinal cord and brain.
4. Motor nerve cells send messages *from* the spinal cord and brain to the muscles, both voluntary and involuntary.
5. A nerve is made up of sensory and motor fibres bound together.
6. Reflex action is action which is carried on in the nervous system without the action of the will.
7. The brain consists of the big brain, the little brain, and the spinal bulb.
8. The big brain is where we feel and know. The little brain helps to control movement. The spinal bulb governs the beating of the heart, the breathing of the lungs, and the circulation of the blood.
9. Too much strong drink poisons the brain; overwork and want of sleep strain it; lazy habits and too much sleep make it sluggish; constipation and bad air stupefy it; bad habits spoil it.
10. Habit is second nature.

CHAPTER XV.

DISSECTION OF A SHEEP'S BRAIN.

Necessary Apparatus.

A hardened sheep's-brain.

A piece of brown cardboard, to serve as a dissecting board. *N.B.*—This can be rendered inoffensive afterwards by washing with a little weak Condy's fluid, or a weak solution of permangamate of potash.

A scalpel, *i.e.* a surgeon's dissecting knife, or a razor or sharp thin knife.

A piece of the hardened spinal cord of an ox.

Note.—For methods of preparation of brain and spinal cord, see instructions below.

Accessory Apparatus.

A good diagram of the nervous system.

Directions to Teachers.

Get the butcher to remove the brain of a sheep from the skull. A rabbit's brain may be used if preferred, but it is so small that it is advisable to use that of the sheep. If the butcher removes the brain, it is well to provide him with a vessel containing the necessary chemicals, and also with cotton-wool. Ask him to remove it very carefully, so as not to injure it, and also ask him to leave the "strings" as long as possible. If you do the work yourself, proceed as follows:—

Saw across the skull in front, just behind the eyes, and saw round backwards on each side, until you come to the opening where the spinal cord joins the brain. Remove the piece of bone carefully; it will be a rough triangle in shape. Work round the brain between it and the skull with a flat blunt instrument, such as a paper-knife, and detach the brain and its membranes from the skull. The white strings which you will see going to eyes, ears, and nose, etc., are cranial nerves. Cut these through as near the bone as possible so as to be more easily seen afterwards. Have ready a thickish piece of cotton-wool and wrap the brain in this, leaving it specially thick on the side it will lie upon. This prevents it from getting flattened before it hardens. Have ready a wide-mouthed jar, or small bowl, and in it the following solution, which a chemist will make up for you for a few pence:—

Potassium bichromate	10 grammes.
Formalin (formaldehyde 40 per cent.)	20 c.c.
Water	500 c.c.

Put the brain into the solution, which must completely cover it, and lay it aside for a fortnight. Then take it out of the cotton-wool and wash it

well in running water for three hours, to get rid of the chemicals. Do not omit this. The potassium bichromate colours the cell tissue, that is to say, the grey matter of the brain (cortex), but it leaves the fibrous part white, and the distinction is very clearly seen. The organ should be quite hard and firm.

If you wish to harden a brain rapidly, use the following mixture:—

5 per cent. formalin	350 c.c.
95 per cent. alcohol	150 c.c.

The brain will be as hard as india-rubber in thirty-six hours, but both the tissues will be bleached by the alcohol, therefore it is far preferable to use the first mixture.

HERE is a sheep's brain which has been made hard and firm by being kept some weeks in chemicals. It is lying on the board in the position in which it lies in the skull. Is it flat or rounded on the top? Rounded. Is the top of your head flat or rounded? Rounded. Yes, it is rounded to fit the brain closely. Which is the broader end? The back. Yes, the front is usually a little narrower than the back, and the broadest part is between the ears. People with broad foreheads have usually more brains in front than people with narrow ones. The front part of the brain is the intellectual part, so we should all like to have good broad foreheads. Here, on the top of the brain, is a torn piece of very tough skin, which has once covered the brain all over (dura mater); that membrane lines the skull and protects the brain, it also goes down and protects the spinal cord. What is the surface of the brain like? Smooth and rather shiny. That is due to other membranes which grow closely over it (pia mater and arachnoid membrane). The fine membrane which grows so closely on to the brain (pia mater) helps to nourish it, as it is very full of blood-vessels, which divide into finer and finer branches and, diving inward, carry fresh air and food with them. These membranes are also called *meninges*, and inflammation of them is called meningitis.

These swellings on the surface of the brain are its folds or convolutions. If we break through the membrane we can pull two of the convolutions apart and see that there is a deep division between them. Such a division is called a *fissure*: there are several big fissures which divide the brain into what are called *lobes*. Which is the big brain? The two big oblong masses in front. What divides them? A deep fissure (median fissure). Yes, so we have a right and left half of the big brain. Each half is called a hemisphere. The fissures and lobes are rather difficult to understand, so we will not say much about them; but I want to show you the two smallest lobes, because they are very interesting. I will turn the brain over, and under the front part I will slip the back of the knife under two little narrow bits of the brain, lying flat against the parts over them. These are the lobes of smell

(olfactory lobes). They lie just over the root of the nose, and send nerves down into it to find out about smells and to tell the brain. I will now turn the brain over again. The two front parts of the two hemispheres are called the two frontal lobes. What is the biggish lump which lies behind the big brain? The little brain. It too is divided into hemispheres, but not so distinctly as the big brain. Now I will lift up the back of the little brain and look underneath. What do you see? Four little bodies, like large peas close together. These are known as the fourfold body (corpora quadragemina). They are masses of grey matter; that is to say, they are composed of cells and have to do with our powers of seeing, for they are connected with the nerves of sight in the big brain.

Now I will turn the brain over, so that the flat under-part is again uppermost. What is this thick white cord running up to the little brain? The spinal cord. Does it alter its size? Yes, as it passes beyond the little brain it swells out. What is that part called? The spinal bulb (medulla oblongata). Notice that it is bound to the little brain on both sides, and remember that really a bridge of nerve fibres is passing across it from each hemisphere of the little brain, telling each side what the other is doing (pons Varolii).

Now I will cut the whole brain very carefully in half. In doing so I have to cut through that band of fibres which goes from one side to the other of the big brain, bringing messages from the grey matter of the cortex, which is composed of cells, to cells in the grey matter on the other side. I will take care not to cut through any other part of the big brain, but I shall cut the little brain in two and also the spinal cord. See, I put the knife into the fissure in the middle and cut straight down through the whole length.

Look first at the big brain and tell me what you see. Convolutions all over it on the inside of the hemisphere, and below them a thick curved band of white. That is the band of fibres cut across (corpus callosum), which joins one side of the brain to the other. Where is the grey matter? On the outside, but it dips down into the depths between the convolutions.

Now look at the little brain. Is the arrangement of the grey matter the same as it is in the big brain? No, not quite, for it and the white matter are arranged in such a way that the white takes a shape very like a tree, and this part is known as the tree of life (arbor vitæ). By lifting up the little brain and cutting away the membrane covering the spinal bulb, we can find the half of a small space or chamber; this, in life, contains a fluid rather like lymph. There are five such chambers in the brain, and they are called *ventricles*. All, except one, communicate with each other. The one we have just found

is the fourth ventricle, and is continued all down the spinal cord as a fine tube, also containing fluid (cerebro-spinal fluid).

Now we will cut level slices off the top of the big brain and examine the arrangement of the white and grey matter. We shall find some masses of grey matter (basal ganglia). We shall do this to one hemisphere only, and then we will cut downwards in the other hemisphere, instead of cutting on the flat, and we shall find out more about these masses and more about what a curious and wonderful thing the brain is. If we were to try to learn about all the things we can see in it, we should find it a very difficult study.

Here is a piece of spinal cord which has been hardened. Do you see anything coming out of it? Yes, white strings. Can you tell me what they are? Yes, nerves. Notice that each nerve has two roots and joins together afterwards. In the root at the back lie the sensory nerves—the nerves of feeling. Do you notice anything on this root which is different from the root in front of it? Yes, it has a little swelling on it just before it joins the other nerve. That is called a *ganglion*, and in it are the sensory cells, and they send one fibre inwards to touch motor cells, or cells of movement, inside the spinal cord, and another much longer fibre outwards to the skin, to discover what is going on outside. Later on we will find out how these fibres end in the skin. The other root is formed of fibres coming from grey matter in the spinal cord, and is a motor nerve. When the two are joined together they form a trunk nerve, like double lines on a railway track, with up and down trains. The messages do not get mixed, for the fibres are carefully packed round with their sheaths, much as an electrician wraps an electric wire in silk to prevent the electricity from escaping.

Now we will cut straight through and across the spinal cord and look inside. What do you see? White and grey matter. Is the grey matter on the outside, as it is in the brain? No, it is in the middle, and takes a shape like a butterfly. The white matter is made up of the fibres going out from it and going up and down the cord and also coming in from the sensory cells. If I roll the cord a moment between my finger and thumb, I make it easy to see the little central canal which runs up into the fourth hollow space or ventricle in the brain which we found behind the little brain (cerebellum) at the back of the spinal bulb.

The way the fibres and cells in the spinal cord are arranged is not easy to learn about, but we can notice another thing, easy to see, and that is, that in this piece of spinal cord the top end, which belonged to the neck of the animal, has the nerves much closer together. The nerves for the front limbs branch off here. Also, if we had a piece of the

lower end of the cord we should see a large number of nerves branching off together. If we look at a representation of them in a diagram we shall see that they look rather like a horse's tail. The big nerves for the legs branch off here. They run down the whole limb, carrying messages of movement, and contain also sensory fibres running upwards and telling us when our feet are cold, and when we are walking, and whether what we are walking on is hard or soft.

We can understand now a little of what happens if we walk on something that hurts us and therefore hurry to get off it. Tell me what happens. Nerves in the skin have been pressed on very hard and perhaps unevenly, and messages go up the nerves to the little sensory ganglia on the back roots of the nerves. The sensory cells send the messages on to motor cells inside the cord, and fibres in the cord, sensory ones, send the message on to the sensory cells in the brain, and the person feels the pain and sends a message down to motor cells in the spinal cord, and fibres from them go out to muscles in the legs and the muscles contract and act and the person moves away from the place that is hurting him as quickly as is possible. The brain also can tell other parts of the body how to help, and perhaps several other parts of the body take a share in rescuing the person from what may have possibly been a real danger.

So we have learnt that the brain is the captain of the body and looks after its safety. We will take care not to do foolish things to injure such a wonderful organ. We want to be captains of our own minds and body when we are men and women, and not be the slaves of a habit which our brain warns us is bad, or be so weak that we have to be looked after and kept in order by other people. If we want perfect freedom, we must learn to love the things that are wise and good and do no harm to others. We must always try to do our duty to the very best of the powers that God has given us.

CHAPTER XVI

SPECIAL SENSES: THE EYE.

Necessary Apparatus.

An orange.
A hand looking-glass.
The convex lens from the spectacles of a "long-sighted" person.
The concave lens from the spectacles of a "short-sighted" person.
A candle.
A piece of tissue-paper.
A diagram or model of the eye.

Note.—If dissection of a bullock's eye can be done, then the next chapter should be combined with this. If, however, it is not thought desirable, then at any rate it is well to get the fresh lens from an eye and to demonstrate with it.

Additional Apparatus.

A compound microscope.
Anatomical slides of sections of the eye.

Note.—Many other experiments can be inserted by the teacher, on the lenses and light rays, if thought desirable. Information must, however, be sought from fuller works.

We have learnt, when we were speaking about the nerves and brain, of how certain cells in the body acted as scouts or sentries on the look-out, and sent warning to others as sensitive as themselves, who made it their business to act on the news received, for the good of the whole body. We learnt how the brain was set over them all. We know that messages are streaming in from all round the body, and we will now try and divide those messages up into different kinds. I want you to tell me of them. What messages are you getting now? Are you sitting at a desk? Yes. How do you know that you are? Well, you can *see* the desk. Then what is that sense or feeling called whereby you can see? The sense of sight. What do you see with? Eyes. Yes, the eyes are the organs of the sense of sight. But shut your eyes. Now, if you did not know where you were, could you find out? Yes, you say. How? By feeling all round with your hands and by touching the place you are sitting in with different parts of your body, and also by remembering what a desk looks like; that is to say, that you find out by the sense of *touch*.

Supposing someone gave you an orange. How would you be able to tell it was an orange? By seeing it and recognising it as being like that which you know by experience is called an orange; that is to say, you can see it is round, and its colour is deep yellow, and it has a certain kind of skin and certain marks that you are accustomed to associate with the name "orange." Can you make sure in any other way? Yes, you can *feel* it is about as smooth and firm as other oranges that you have known, and you tell that by the sense of touch. It is also cool, and that you know by the sense of *temperature*, which is part of the sense of touch. It is also the usual size of an orange and about the usual weight. That you can tell by holding it in your hand and moving it up and down. You know all this by the *muscular sense* or sense of pressure and resistance in the muscles, and that too is part of the sense of touch. Anything else? Yes, it has the *smell* of an orange, and that you know by the sense of smell. Could you make sure any other way? Yes, by *tasting* it; that is to say, by the sense of *taste.* Lastly, someone might say to you, "It is an orange," and you would learn about it by the sense of *hearing.* So five different kinds of messages have come into the brain, telling us about this orange, and the messengers have been nerve cells in the eyes, the ears, the tongue, the skin, and the nose. These senses are like five broad roads, along which messengers run, to give different kinds of messages to the brain. In a sense they are also like lines of telegraph wire along which messages flash up to the central station. It is evident, then, that the more roads we learn by, the more we shall know about a thing. That is why we have object-lessons in school, so that all the roads of learning shall be opened and kept in good condition. The eyes are the windows of the mind. Nature takes care of them: she covers them with eyelids to protect them from too much light, and she fringes the lids with lashes to keep out the dust. She gives us eyebrows to prevent perspiration from trickling down into the eyes, and she makes salt water flow continually over them from a tiny gland (lachrymal gland) in the outer side of the eye, and so wash away specks of dirt, and this water disappears down little tubes or ducts leading from the eyes into the nose. If our eyes are hurt by anything which makes them water, or if we weep, so much of this salt water may be made that it cannot all escape by the openings of the ducts, but overflows as what we call *tears.* The eye is really a ball set in a socket, and containing cells which in a wonderful way catch the rays of light and pass the impressions on to the brain by nerve fibres bound together to form the nerve of sight (optic nerve). The eyeball itself is a round chamber. Its walls are strong, and consist of three separate coats. The nerve of sight comes straight from the brain and enters the eyeball at the back. The

fibres of the nerve branch out all over the back of the eyeball, forming a sort of network. They end in very delicate cells, highly sensitive to

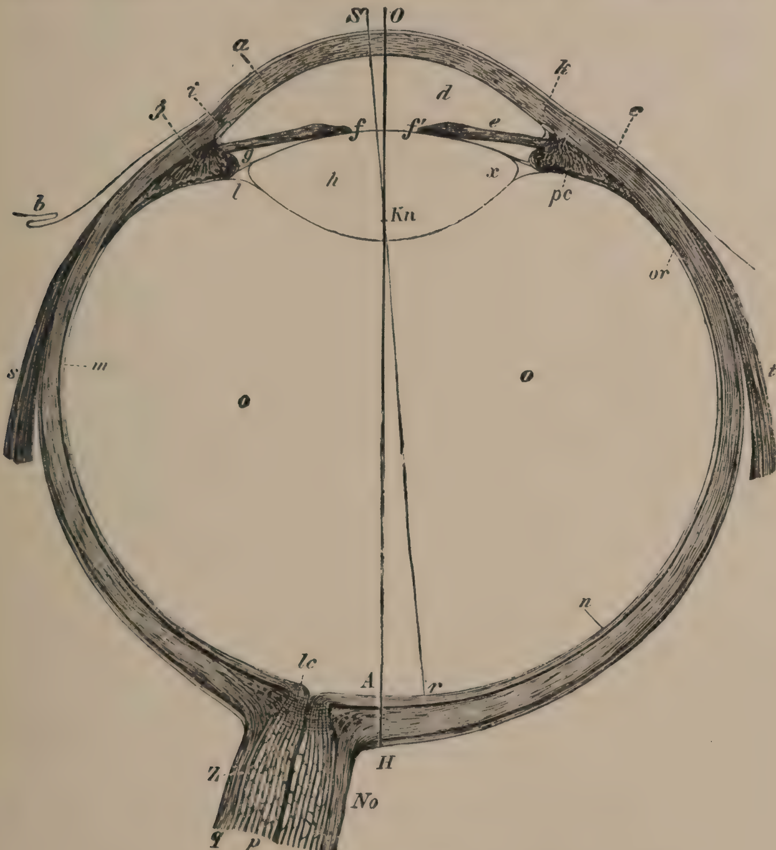


FIG. 57.—Diagram to illustrate the spreading out of the Optic Nerve to form the Retina.

a, cornea. *b*, conjunctiva. *e*, iris. *f*, pupil. *m*, choroid. *n*, retina. *No*, optic nerve. *q*, nerve sheaths. *p*, nerve fibres. *r*, fovea centralis.

light, and when they are stimulated by it they pass the stimulus on up the fibres of the nerve and it reaches the brain. This network of cells and fibres is called by a Latin name, *retina*, meaning a *net*, and,

like a net, it catches something, since it catches the rays of light. If you look at someone's eye, or your own in a glass, you can see a coloured part in the middle and a white part round it. That white part is the outer one of the three skins or coats of the eye (sclerotic), and the part in the middle is a portion of it made transparent like glass, so that you can look through and see the coloured parts underneath. This transparent part is called the *cornea*, and is curved. Look at someone's eyes in a place where there is little light, or turn him or her with back to the light. Now notice the very centre of the eye. What colour is it? It is black. Notice its size. Now make the person look at a bright light and examine the eyes again. What do you notice? The black part in the middle of the eye is smaller. That is a very curious thing, is it not? This part is called the *pupil* of the eye, and is really a round opening like a window, covered with the cornea as with a glass. As you look through it, you are looking right into the inside of the eye. But, first, you look through a transparent little body just behind the opening of the pupil. This body is called the *lens*. Behind that, as we have already said, you are looking into the centre of the eye itself, and that is filled by a glassy, transparent substance (the vitreous humour). The pupil of the eye looks black, because the inside of the ball of the eye is, as it were, lined with a very dark blue-brown lining, with a thin and almost transparent membrane over it. We have already heard of the three coats of the eye. The outer one is very tough (sclerotic); next to it comes the dark, almost black, one (choroid); lastly, and inside of all, touching the glassy substance in the centre, is the *retina*, the most wonderful and delicate of all. This, as we have already heard, covers, not the whole of the inner walls, but a great part of them, since it covers all the back and most of the sides of the ball. This delicate membrane is, as we have learnt, made up from the fibres of the nerve of sight and their end cells. To protect, look after, and help it, all the rest of the eye has been developed. The retina is a pinkish colour, because it is very richly supplied with blood-vessels.

The part of the dark coat just behind the retina is brilliantly coloured in some animals in bluish-green tints, and this, in certain lights, makes their eyes glow very curiously. Cats' eyes are a well-known example of this. Now look at your eye in the glass and tell me what you see round the pupil. A coloured part, which is of a different colour in different people, perhaps blue, perhaps grey, perhaps brown, and sometimes so dark as to be almost black. That part is called the *iris*, and is really a part of the coat underneath, coloured differently and with that round opening in the centre which we have learnt to call the pupil. Now, the curious thing about this iris is that

it is really a round curtain, put over the window of the pupil, with a hole left in the middle. In it are involuntary muscle fibres, supplied with nerves. Some of these fibres run round it and others run from the outside to the central opening. If the light stimulates certain nerve fibres and they in turn stimulate the muscles, then the curtain either moves back, by shrinking together as the muscles contract, or else moves forward, according to which fibres are stimulated. If it moves forward, the pupil becomes more covered and appears to grow smaller. The reason why this happens is that the eye is injured if too much light passes through the window, therefore the curtain comes forward to cut it off, and the movement of the curtain in this is curiously like what we do when we pull the running-string at the mouth of a bag and so shut it up. If there is very little light, then the curtain moves back and allows as much to enter as possible. In certain cases of poisoning, opium poisoning for instance, the curtain becomes closed, all but a tiny pin-point. Whereas, if certain other poisons are put actually into the eye, different fibres are affected and the curtain is drawn back so much that the pupil may become enormous, and the person cannot see properly, for too much light makes the image of the thing he is looking at quite indistinct, and he is "dazzled."

Behind the iris and the pupil is the wonderful transparent structure called the lens. This lens forms the back of the front chamber of the eye, and the space between it and the cornea is filled by a watery fluid called the aqueous humour. The iris floats smoothly in this water.

Here is a pair of spectacles belonging to a person who has what is often called "old sight." Notice that the glass is thin at the edge and becomes thicker in the middle. A glass shaped like this is called *convex*. Here is the lens belonging to the glasses of a short-sighted person. Is it the same as the other? No, it is thick at the edge and thin in the middle. Such a lens is called a *concave* lens.

Now I will take the first lens, and light this candle, and darken the room. Some of you can come and stand beside me. I will hold the lens out at arm's-length in front of the candle flame. What can you see? A little picture of the flame. Where? Between our eyes and the lens. Is there anything else you notice? Yes, the flame is upside down. Now here is a smooth, clean piece of tissue-paper. I will hold it up between us and the lens and move it backwards and forwards. What do you notice? At one place the picture of the flame becomes very clear and seems to be between us and the lens. The distance between the lens and the paper, when such an image is found clearly, is called the *focal* distance of the lens, and it differs for different lenses. The more bulging or convex the lens is, the shorter is the focal distance. Light striking an object is bent back or *reflected* from it in rays, and

if we pass these rays through a convex lens they are bent towards the middle, and, on coming out on the other side, they meet at a certain

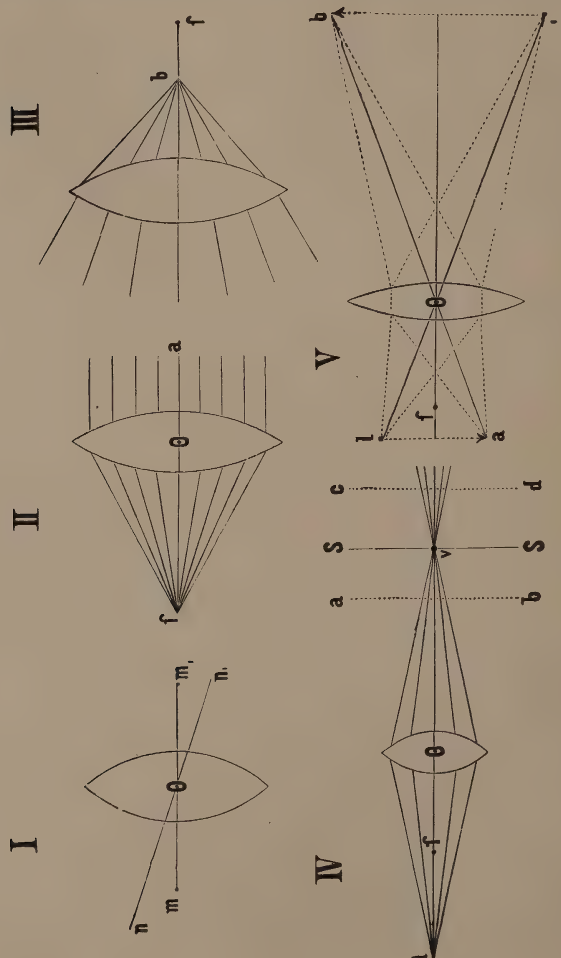


Fig. 58.—Figures illustrating the action of lenses upon rays of light passing through them.

distance away, and that distance is long or short according to the bulging or *convexity* of the lens. At the point or focus where these

rays meet a real image is formed, as we have seen, and formed upside down. Rays which gradually come closer together as these do are called *converging* rays.

I will now hold up the concave lens and the paper as before. Do you still see the clear image in front? No. All we seem to see is an image *behind* the lens on the same side as the flame. Rays passing through a concave glass are diverged—that is, they are spread wider apart, nearer the edge of the lens, and when they leave it they get wider and wider apart. The rays seem to start from a point behind the lens; but it is not a real image, only an imaginary one.

Now, the lens in the eye is convex on both sides, and is slung in its place in a transparent and very delicate membrane called the capsule of the lens, and attached all round to a muscle called the ciliary muscle. This muscle is attached to the middle (choroid) coat, and pulls more firmly on that part of the membrane in front than on that behind. In consequence, as the lens is soft, it is slightly flattened by the pressure on it in front. Behind the lens comes the clear glassy humour which fills up the ball of the eye and is touching the retina at the back.

The retina itself is only very loosely attached to the middle (choroid) coat beneath it; but it is quite firm at one place. If we were to look at the back of the eyeball from the outside of it, we should see a cord coming into it from the brain; this cord is the nerve of sight (optic nerve) (see fig. 57 *No*). It enters in the middle of the back, but a little to the inner or nose side. This nerve has thousands of fibres in it. As these fibres spread out to form the network of the retina, they are connected with some very wonderful cells in it. Thin as the retina is, many different layers have been noticed in it; but the layer of the strange cells called, because of their shape, the *rods and cones*, is the lowest of the layers, and is at the top on the diagram (fig. 59), because we are counting from the outside layer to the innermost one. This innermost one is, of course, touching the clear glassy humour which fills up the ball of the eye. The rods and cones are the special cells which are set aside to give information about the outside world. Just in the middle of the retina, and opposite the middle of the lens and a little bit to the outer side of the eyeball, is a place called the *yellow spot* (macula lutea). Here most of the layers are thinned out, and there is little else but the rods and cones and the necessary fibres of the nerve. Here it is that we see most clearly. If we want to see a thing well, we must move our eyes about by means of the muscles which are attached to the eyeball on the outside, whose nerves arise in the brain [1] As we do so, we allow the rays of light from all parts of the object to reach the yellow spot, and

[1] See next chapter.

so give the cells accurate information about every portion of it. There is one part of the eye, however, where we cannot see at all, and that is where the nerve comes in. There, there are only fibres beginning to spread out; there are none of the rods and cones doing sentry duty; and therefore this place is as blind as your hand. Let us see if we can prove this. Hold up your thumbs at arm's-length, straight in front of your eyes and close together. Shut your *left* eye, and fix the right eye on your left thumb-nail. Never take your eye off this left thumb-nail to look at the other one, which of course you can also see. Can you see both nails clearly? Yes. Now very slowly move your right thumb away to the right, but on no account take your right eye off the left thumb. Keep both thumbs in a straight line with each other as you move your arm. Can you still see both thumb-nails? What happens after a few inches? The top of the right thumb disappears entirely. Move it a little more to the right. What happens? You can see it clearly again. Why is this? It is because the rays of light, travelling from your thumb, strike the retina just where the nerve of sight comes in, and therefore where there are no rods and cones; as a consequence you cannot see that part of the thumb. But when you move the hand a little further along you bring the same portion opposite a part containing the rod and cone cells, and they at once send on the information concerning it to the brain. The nerve of sight and the fibres and cells of the retina are really direct outgrowths

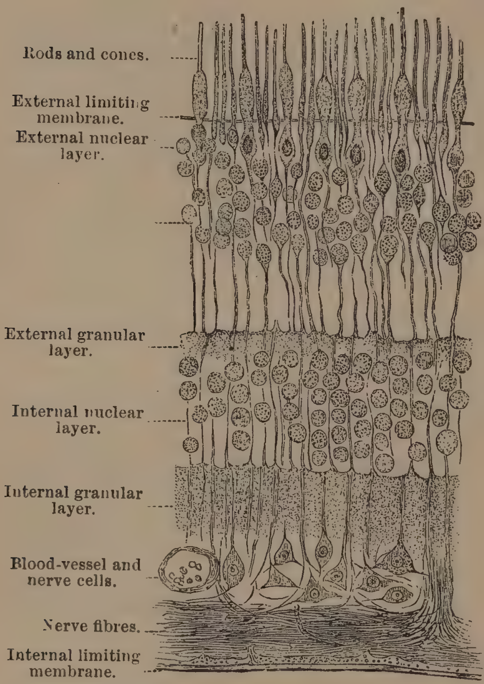


FIG. 59.—Vertical section of Retina.

of the brain, and that is why it is so easy to get a headache if we strain our eyes.

Now that we understand a little about these things, let us imagine straight rays of light from a distant object striking on the eyeball. What part do they go through first? The transparent cornea. It bends them a little. What do they enter next? The watery humour. It bends them a little more. Now they pass through the open window of the pupil, and the iris cuts off the outside ones just as a photographer can cut off the outer rays of light in a camera by using different stops or diaphragms, and so gets only the clear centre rays. Directly the rays get to the pupil, what do they find? The lens. Yes, and the lens in its unaltered condition bends the rays strongly and converges them just enough, so that when they have passed through the glassy humour in the centre of the eye they have had just sufficient length, in the ordinary healthy eyeball, to bring them sharply to a focus on the retina, where they stimulate the cells. So there is no trouble at all for rays from distant objects which travel in parallel lines—that is to say, lines which keep an even distance from one another. But all rays do not do so. Rays from near objects *diverge*—that is to say, they are getting wider apart from each other as they travel onward. When they enter the eye they become bent towards each other, but unless they are bent more than the parallel rays from distant objects they will, since they are wider apart to start with, not have had length enough in the eyeball to come to a focus when they strike the retina; therefore only a blurred image will be seen. How is this to be altered? The photographer does it by making his camera longer; but the eye does it differently, by making the lens bulge more. The ciliary muscle is stimulated and contracts in such a way that the middle coat to which is attached the transparent ligament, which holds the covering in which the lens is slung, is pulled forward, and the pressure of the covering (or *capsule* of the lens, to give it its correct name), is lessened. Directly that happens, the lens inside bulges forward and becomes more convex in front. If you press with your hand on an india-rubber ball, you can flatten it, and your hand does what the capsule does. If you take your hand away, the ball becomes round again. This is what happens in the eye. This power of the eye to alter for different rays is called the *power of accommodation.* The rays being more sharply bent have now room to come to a focus, and the person sees clearly. We learn from this that a person with ordinary sight only uses the ciliary muscle when looking at things that are near. The muscle becomes tired if we look at near things too long and keep it on the strain; therefore it is good for the eyes to rest them by looking at distant objects from time to time. Sometimes people suffer

from having eyeballs which are shorter from back to front than they ought to be, and they cannot see clearly unless they use the power of accommodation even for parallel rays, and, of course, they have to use it still more strongly for the rays from near objects. Such people often suffer a good deal from headaches and in their general health, and yet have no idea that it is in any way due to their eyes. This condition (hypermetropia) means that the eye never gets any rest, for the muscle has to work whether the eye be looking at far things or near things, and nerve power is continually being used up. If the person becomes tired or run down, or does a little more work than usual, he may suffer in various ways. Sometimes he seems to have bad bilious attacks, sometimes bad indigestion.

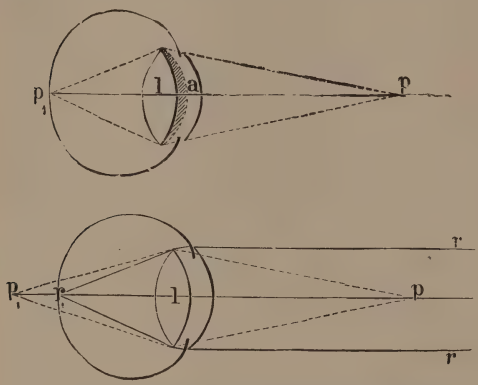


FIG. 60.—Condition of Refraction in the normal *passive* Eye and during *accommodation.*

It is not so very long ago since this became known, and now doctors often find out that people are suffering from eye-strain and need glasses, when before they would have been given medicine. As soon as they get proper glasses, the pains and troubles disappear. In later life, power of accommodation lessens and also the eyeball shortens (presbyopia). People between forty and fifty often have to take to glasses. Of course, all these people wear convex glasses, because they need to make the rays bend quickly. Sometimes very old people, who have worn glasses for years for near things, suddenly find that they can see quite well without them. That is because sometimes in old age the coats of the eye get soft and stretched and

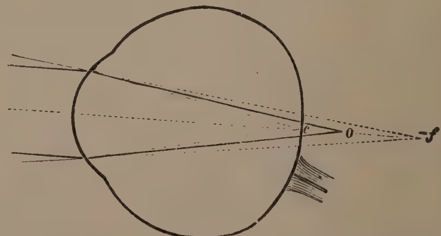


FIG. 61.—"Long-sighted" or Hypermetropic Eye.

the eyeball gets longer again in consequence, but this does not often happen.

In some cases eye-strain is the result of the cornea of the eye not being evenly curved; therefore rays passing through it are bent irregularly and pass through the lens at different angles, and so do not all focus properly. This is very common (astigmatism), and can be corrected by proper glasses.

Now we come to the subject of short sight. Short-sighted people have long eyeballs (myopia). Rays of light from distant objects arriving in parallel lines are bent as usual, but they come to a focus just where in an ordinary eye the retina would be. But of course, as this eye is longer than the ordinary eye, the retina is further on, and the

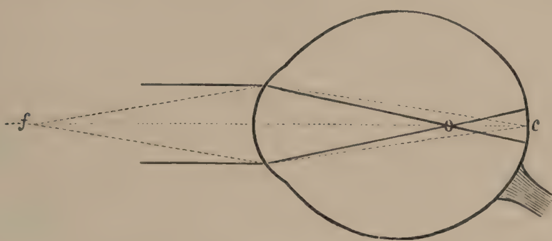


FIG. 62.—"Short-sighted" or Myopic Eye.

rays come to a focus in front of it and then divide, therefore when they reach the retina they are apart, and make only a blurred image. But for near things, the rays, being already apart, get bent quite enough in passing through to bring them to a focus at the back of the long eyeball without the need of having to bend them more by the use of the ciliary muscle, since there is no necessity to make the lens more convex. Short-sighted people, therefore, can never see far off-things clearly without help, for there is no power in the eye to do anything to the lens except to make it more convex, and that would only make matters worse. Nor is there any way of making the eyeball shorter. If these people wish to see distant objects clearly, they must use a concave glass—that is to say, one thick at the edge and thin in the middle. Then the rays will reach the eye already divergent or apart, as if they came from near objects, and will therefore come to a focus later. Short-sighted people with their long eyeballs can do fine work and look at near things without straining their eyes by having to use the ciliary muscle, whereas the so-called long-sighted person with the short eyeball never rests the muscle at all.

We must not confuse the expression "long-sight" (hypermetropia) with what we mean when we say that such and such a person is wonderfully long-sighted. In this last sense we mean that he can see for an unusually long distance, and in the other we mean that he can only see far things well.

Children have naturally short eyeballs and see far-off things more easily than near things, for, on looking at near things, they have to use their ciliary muscle a good deal. Their eyes do not reach full development till they are eleven years old. Teachers often have to make children leave off reading and look at something far off in order to let them rest their eyes a little. It is also bad for children to hold a book close to their eyes. Sometimes if children's eyes get a little tired by looking at something near and having to use the eye muscle a great deal, they give up using the muscle without knowing it, and then they see so badly that they bring the book nearer and nearer in order to make the image of the print seem larger, and this larger and better lit image makes up a little for the bad focus. When teachers see this happen, they have to judge as to whether it is done because the eyes are a little tired, or because the child is getting into a bad habit. Remember that you hurt your eyes and make yourself short-sighted if you hold the book close to your face and stoop over your desk. The eye can be trained by habit to read at a certain distance, and it is not good for it to be very near the book. If the ciliary muscle is always pulling, it stretches the coats; and if the head is bent, though it is easy for the blood to get into the head and therefore to the eyes through the firm arteries, yet it is difficult for that same blood to get away quickly through the soft veins, which are being pressed upon when the head is bent. The flow of blood being thus slightly hindered, the coats of the eye are likely to get a little strained by the large amount of blood in them, and especially the outer coat, which in a child is still soft. If that and the second coat stretch, then the eyeball will become too long and short-sight will be the result.

Try, therefore, to remember to sit upright at your desks and not stoop, and do not hold your book closer than about twelve inches away from your eyes. We must not strain our eyes by reading bad print, and especially in a bad light. Reading with the light right in front is tiring to the eyes. The best light is that which comes from the left, for then, as we write, no shadow of our hand is cast on the book. The next best is that which comes from behind.

Dust and dirt irritate the eyes, and if we have been in much dust it is well to wash them with clean warm water. If the eyes are red and inflamed, they may be bathed often during the day with weak

boracic lotion, or Condy's fluid. Use a clean rag or cotton-wool, but never a sponge when the eye is inflamed. If the inflammation continues, the doctor must prescribe. Weak inflamed eyes often mean general poor health, and they get better with good air, good food, and cod-liver oil; but inflammation must never be neglected, as it may be both infectious and dangerous.

If a sharp piece of dust gets into the eye, we must not rub the eye backwards and forwards, for we are apt to make the dust, which may be sharp and hard, stick into the eyeball and scratch it. The eye can, however, be gently rubbed towards the nose, but it must be done *very* carefully. It is at the corner by the nose that the dust is likely to be washed out by the water of the eye, the *tears* which come from the little gland at its outer corner. Blowing the nose hard helps to draw the moisture forward, and the dust with it. If this does not succeed, we can try pulling the upper lid down over the lower one by taking hold of the eyelashes. We can do this two or three times. If the dust is sticking on the inner side of the upper lid, the eyelashes of the lower lid may brush it out. It is best not to meddle too much with the eye, but go to a skilled person and have the troublesome thing carefully removed by the proper means. If what has got in is very painful, then it is best, before going to the doctor, to keep the eye still by putting a big soft wad of cotton-wool on it, and then a bandage, sufficiently firmly to press gently on the eyeball and prevent it from moving; or a drop of castor-oil in the eye, by coating the rough substance, may give relief.

We occasionally, when travelling in a train, get sharp bits of metal or cinder in the eye; sometimes too we get a spark in it; and we go on pulling the poor eye about to try to find what we think is a piece of something but is really a rough place caused by the burn, and so we often inflame the eye very much. It is better in such cases to bandage the eye and to wait to see a skilled person. If it has been slightly burnt by a spark, a night's rest and quiet with the eye bandaged will probably put it to rights again.

Certainly our eyes are very wonderful and precious things, and we need to take good care of them.

Now we will make a summary of some of the many things we have learnt:—

1. There are five different ways in which cells give us news of the outside world. These ways are called our five senses.

2. The five senses are: sight, hearing, smell, taste, and touch.

3. The sense of sight is situated in the eye, which focusses the rays of light by means of a lens on to the retina.

4. The retina is the end of the nerve of sight, spread out like a net at the back of the eye.

5. The nerve of sight carries the messages to the brain.

6. It is very bad for the eyes, especially in childhood, to stoop the head very much over a book, or to read in bad light.

7. Read good print in good light, keep the head well up, and do not hold your book too near your eyes.

CHAPTER XVII.

SIMPLE DISSECTION OF A BULLOCK'S EYE.

Necessary Apparatus.

Two fresh bullock's eyes. Ask the butcher to cut the "strings" as long as possible.

A piece of cardboard, preferably dark in colour, on which to dissect the eye, which will adhere fairly firmly to the board, making the work of dissection easier.

A sharp penknife, razor, or "scalpel."

A pair of dissecting scissors, or sharp manicure scissors.

A piece of printed paper, on which to display the magnifying power of the lens.

Note.—If it is desired to show the layers of the lens, provide some 1 per cent. solution of potassium bichromate and a small jar, and keep the lens in it for a week. The coats of the lens can then be peeled off like the coats of an onion.

We have here two fresh bullock's eyes, and we will do a little simple dissection which will help us to understand our lesson on the eye better than pictures and diagrams can do.

First of all I will clear away the fat. What does the fat do? It pads round the eye in the socket and protects it. When people get very thin, this fat wastes away, and we say that they are hollow-eyed. I am going to snip away all this fat, and also clear away this loose skin, which is the conjunctiva, or skin which lines the eyelids and is continued forward over the eyeball. As I cut the fat away, we see red bands of muscle fibres. These are the muscles which move the eyes in all directions. Notice that four of them are straight. There are two others which are called the oblique muscles, but they are probably cut off so close that it is difficult to show them very plainly. One starts from the back of the eye-socket and runs along the roof, passing through a loop of tendon at the edge and then in a slanting direction to end on the top of the eye; the other one is fastened to the eye-socket on the lower and inner side near the front; and these two roll the eye when they contract. All the muscles are supplied with nerves coming straight from the brain through the bony walls. At the back of the eye do you notice anything? Yes, a little bit of cord, like a piece of

thickish string. It is cut off rather close to the eye, but still it is quite easy to see it. What is this? It is the optic nerve, the nerve of sight. Notice that its outer covering is the same as the outer covering of the eye (sclerotic), with which it is continuous. Where does it enter the eye? At the back, a little below the centre and rather to the inner side. We know which is the inner side, because the wide part of the transparent part of the eye (cornea) is always at the inner side near the nose. Now look at the front of the eye. Notice the round clear front part. What does it seem a part of? It seems to be an altered part of the greyish-yellow outer coat. This outer coat is very tough and strong, and supports the eye well. Notice how the cornea bulges forward in front of the eyeball rather like a bow window, or like a curved watch-glass. Now I will steady the eye very firmly between my finger and thumb, and take this sharp knife and push the point down firmly through the edge of the cornea. The outer coat of the eye is so tough that it is quite difficult to do this, and it is well to hold the eye so as to get a firm surface. What happens? Water gushes out as the point of the knife goes in. This water is the watery humour (aqueous humour) which we learnt was in the little front chamber of the eye, between the cornea and the lens. We will now use the scissors and, putting the point in, cut all round the cornea and remove it. What do we see now? A thin dark membrane. This is the iris, which in life floats in the watery humour. What is in the centre of it? A slit through which light can pass. In human beings this opening is not a slit: what shape is it? Round. What is the name of this opening? The pupil of the eye. We will lift the edge of the iris and notice how it is fastened, and we will cut it right away, and in so doing we see that it is attached to the second or middle coat of the eye (the choroid).

We have already learnt about the colouring of the iris, and in cutting it away we must notice its inner side. The middle coat is joined on to the iris by what is called the ciliary body, in which are these curious black pleats, lying all round behind the iris. The ciliary muscle is attached to the lens, or rather to the delicate ligament it is held up by. We can see the whitish fibres of the ciliary muscle, close to the cornea on the front part of the middle coat. We will now make a slit in the delicate membrane over the lens and slip the latter out. What is it like? Like a piece of crystal. That is why it is called the crystalline lens. I will lay it over this piece of printed paper. What do you notice? The writing looks much larger; it is magnified by the lens. Are both sides of the lens alike? They are both curved outwards, but the back is slightly more curved than the front. This lens, therefore, being curved outwards, or, in other words, being convex on both sides, is called a bi-convex lens.

What do you notice on the side behind the lens where it was resting? A clear, transparent jelly. This is the glassy (or vitreous) humour. Look through it and you can see where the nerve of sight, or optic nerve, comes in at the back. We are looking straight at the back of the retina, or inner and third coat of the eye. I will now turn out the glassy humour very gently, so as to disturb the retina as little as possible. What does the inner lining look like? Like a very delicate pink skin. We can see tiny blood-vessels through it. The place where sight is best is the exact centre, and the entrance of the optic nerve is a little to its inner side. I will carefully remove the retina from the middle coat, though its dark lining will stick to the latter. Notice that when we remove it, it all comes away except at the optic nerve, and that now we can see quite well that it is really the nerve itself spread out, and is merely a continuation of the nerve. It is in fact formed of the optic fibres without their sheaths, and the optic nerve has about 500,000 fibres in it. The presence of nerve *cells* in the retina proves that in reality the optic nerve is not the same as others, but is really an outgrowth of the brain itself. No wonder that eye-strain is felt in the brain, and that brain-strain affects the eyes.

Notice the green colours in the middle coat. In animals of the cat tribe this is still more marked, as we learnt before.

We might notice a good many more things in the eye, but we have learnt enough to show us what a delicate and wonderful organ it is, and that knowledge will help us not to injure our sight by reading in bad light, or staring at a bright light which fatigues and injures the retina, or reading in bad positions, which may keep too much blood in the eye by the head being too much bent and straining the supporting coats in such a way as to lengthen the eyeball and bring on short-sight.

CHAPTER XVIII.

SPECIAL SENSES: THE EAR.

Necessary Apparatus.

Two ordinary thin paper bags, such as are used by pastry-cooks; one considerably larger than the other, and both without holes.

A tuning-fork.

Accessory Apparatus.

A rabbit's skull to show the ear-holes.

A good model of the ear.

We are now coming to a very important sense, an avenue by which a great number of impressions reach the brain; that sense is the sense of hearing. The ear is another of the special organs developed by the citizens of the body to keep on the look-out for the sake of other cells and give them news. Organs such as the eye and ear are known as "end organs." We know that what is necessary in such an organ is a cell to receive the impression, a thread to carry it, and another cell to receive and recognise it in some way or other. Where is the special cell in the eye? In the retina; though of course we understand that there are a great many more than one. Where is the thread? In the optic nerve. Not one thread, but thousands bound together. Where are the receiving cells? In the brain. Some sensations travel first to the spinal cord and are passed on to the brain in relays, but cells in the eye and ear send their messages straight in. We found out that the cells of sight in the eye are deeply buried and hidden away from danger, and other cells have arranged themselves in a special way to pass light on to them. Let us see where the end cells in the sense of hearing are hidden.

Sound is the result of certain waves produced in what are called elastic bodies, such as air or water. If you throw a stone into a pond, what else do you see besides the splashing? Little waves all round where the stone fell. Where are those waves going? Outwards in bigger and bigger circles till perhaps they break on the shore or die out before they reach it. Light travels in a different way, for it will travel where there is no air; but it comes to us through

the air, and very quickly, at the rate of 186,000 miles a second. It is not possible for us to imagine anything so quick as this. Sound travels at about 1090 feet a second, quite slowly in comparison with light. As has been said by a certain writer, "It is a good thing to imagine ourselves standing on a hill and looking down at a plain, where, far off, men are firing a big gun, and for us to imagine also that we can *see* the splashes and waves of sound in the air, as we can see the splashes and waves in water." We will keep our eyes fixed on the gun. Which of our collections of citizen cells is going to tell us first when anything happens? Look! What is that? A burst of bright flame. Ah! They have fired the gun. We have seen the light; it has travelled at enormous speed, and rays of it have entered our eyes and made an impression on the cells in our retinas, and the message has reached the brain.

But at the same time as we see the light our imagination shows us a great confusion in the air round the gun, and we can see the waves in the air spreading out all round, and, on our side, they are very quickly getting nearer and nearer. Now they reach us and break upon us, and suddenly we hear a roar of sound, and we say, "That is the roar of the cannon." When air is torn apart by electricity in a thunderstorm, we see the lightning almost at once, so quickly does light travel; but sometimes we have to wait quite a little time before we hear the thunder of the masses of separated air, torn apart and rolling together again. We have to wait till the waves of sound reach us. Why do we not know anything about the waves except in our ears? The reason is that by the time they touch us they are so delicate that only the cells of the ear hear them—that is, only these cells are strongly affected by them; but if we are very close to a big disturbance, with great masses of air rushing past us, we should feel them so strongly that we might be knocked down by them, and we might be seriously injured in that and other ways. Let us notice the ear of a human being. The outer part (concha) or shell of the ear is really only the outer ear. This shell is curved and curled in a curious way, which helps to catch the waves of sound and pass them on inside. This outer part of the ear has got a great many names attached to it, about which we need not trouble ourselves. Sometimes, if people are a little deaf we see them making the shell of the ear larger by putting up their curved hand to help to catch the sounds coming to them. The lobe of the ear, as it is called, is the lower part; above it is an opening which is the beginning of a little passage, slightly curved downwards. This passage is part of the outer ear. The passage is lined with active cells, which manufacture a bitter wax from the blood. This wax softens the passage

and is disagreeable to insects. The cells grow from the inside outwards, so that the wax is always being brought along with them. The passage is also set with stiff hairs, as a protection against insects. Some people are very much afraid of insects getting in, but their fear is unnecessary, for the wax is so disagreeable that insects try to turn away at once, and the stiff hairs also prevent them from entering. Sometimes a little tiny fly or moth flies in very quickly and gets caught, but this very rarely happens. The best thing to do, if an insect gets into the ear, is to bend the head to the opposite side, so that the suffering ear is uppermost. Then pour some vegetable oil, such as olive oil, into the ear, and the insect will float up to the top, and can easily be taken out with a little paint-brush, or the corner of a pocket-handkerchief. The oil will not hurt the ear, but will stifle the insect. There is no need to be afraid of the stories some people tell of insects getting into the brain. They cannot do so, for a very good reason. At the bottom of the little passage (meatus), which is only $1\frac{1}{4}$ inch long, we come to a tough membrane or skin which completely closes it, as the parchment on the end of a drum closes the drum, or as you may come to a closed window at the end of a passage. This window is always tightly shut and is not made to open. It is elastic—that is, you can press on it and alter its shape and it will come back again to the first shape as soon as the pressure is removed. It has a muscle attached to it which can pull it tighter. Beyond this window is a very curious little room, which is hollowed out of one of the side bones of the skull (temporal bone). It is a very tiny room, only half an inch high and only 1–3 lines broad. The ceiling is made of a rather open kind of spongy bone, and above the ceiling rests a part of the brain, so that we see that this part of the ear is very close indeed to the brain. The whole of this part is called the middle ear, and is often talked of as the drum of the ear. The membrane at the bottom of the passage is, as regards its position, like the parchment we beat on in a real drum. In the floor of the middle ear is an opening like the opening of a well. This hole or opening is really the beginning of a

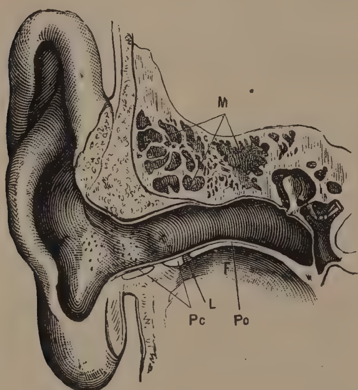


FIG. 63.—Section through Ear.
Auricle, external auditory meatus, and the tympanic cavity.

short tube, made largely of gristle or cartilage, and $1\frac{1}{2}$ inch long. Air keeps coming up this tube; where does it come from? It is very important to have air in the middle ear; we will see why presently. These tubes (Eustachian tubes) in both ears go down into our throats and open in them on each side high up, not far from the tonsils. Every time we swallow, the tubes open, and the act of swallowing forces air up them. They are lined with the same kind of mucous membrane as that which lines the throat, mouth, and nose, and the

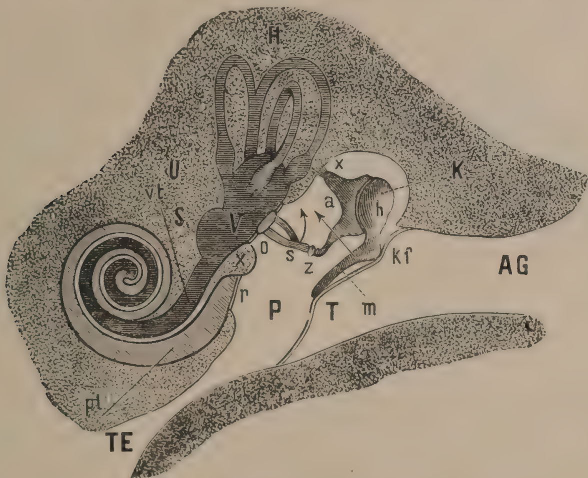


Fig. 64.—Scheme of Organ of Hearing.

AG, outer ear. T, drum of ear. TE, Eustachian tube. K, hammer. *a*, anvil. *s*, stirrup. *x*, beginning of lamina spiralis. *r*, round opening. *o*, oval opening.

middle ear is lined with it also. There are still more interesting things to learn about the middle ear, for, stretching right along it, is a chain of almost fairy-like little bones, three of them. One is shaped rather like a hammer (malleus), and its handle is firmly fixed to the membrane of the drum, while its head is fixed, by a joint, on to a bone which is shaped like a smith's anvil (ancus), and that again is jointed on to the third bone, which is exactly like a stirrup-iron (stapes). The flat part of the stirrup is fixed in the end wall on the membrane closing in a little oval-shaped window. Quite close to the oval window there is another window in the wall, but it is smaller and round. This is the end of the middle ear.

Now we are getting very near the hiding-place of the cells for

hearing. If we got through the end wall of the middle ear we should find the inner ear, which is a very wonderful organ, deeply hidden in the temporal bone. On one side of it are three curious bony tubes, very tiny, and looking rather like the handles of a jug, close to each other, but at three different angles. They open into a wider space of bone which has been called the *vestibule,* or hall, and on the other side of this hall there rises up a double winding passage, like a snail-shell, only you must imagine the passage up the snail-shell divided into two by a membranous tube, attached to each side, so that this membranous tube is like the ceiling of the lower passage and like the floor of the upper one. The membranous passage enlarges into the vestibule and partly fills it, and branches from it run up each one of the bony canals and form a membranous canal inside each one of them. Here are two paper bags; one is larger than the other. I will blow into the small one, and then without giving the air time to escape I will twist the bag up tightly at the mouth. It is now full of air. Now I will put the little bag into the big one and blow into the big one also and twist up its mouth. Now, if the outer one were made of bone we might call it the bony inner ear, and if the inner one were made of skin or membrane we might think of it as being the membranous inner ear. The paper bag which represents the membranous ear has air inside and air outside, and this outer air is of course contained in the outer bag representing the bony shell. Now, instead of air in the inner ear itself, there is a delicate fluid like lymph. You must quite understand that wherever there is air in the paper bags there is fluid in the real ear. This fluid can be made to have waves in it. Inside the membranous tube, which runs up to the top of the bony snail-shell part, are the wonderful cells of hearing, set side by side all along it with delicate hairs or cilia which come from the cells and wave in the watery lymph inside the canal (perilymph). In connection with each cell is a thread or fibre, which pierces the walls of the inner ear and joins its fellows, to make a thick nerve called the nerve of hearing (auditory nerve), which goes to cells in the hearing centre of the brain.

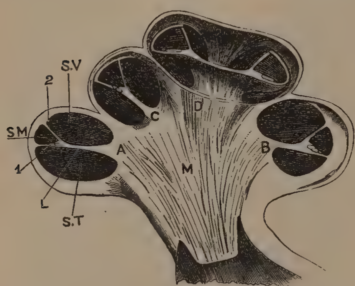


FIG. 65.—Vertical section of the Cochlea.

S.T., lower bony passage. S.V., upper bony passage. S.M., membranous passage. These passages are filled with lymph.

Here is a tuning-fork. If I hit the fork smartly on the edge of the

desk, what happens? It gives out a sound—a note of music. This fork is trembling or vibrating from the blow, and as it moves backwards or forwards in its vibrations it first gives a little shock or blow to the air on one side and then moves back to give a blow to the other side. As it presses forward it of course presses the air in front of it closer together, and as it moves back that same air recoils and waves are set up by the vibration of the fork. We will imagine a fork vibrating at the rate of 300 times a second and making a corresponding number of air waves. Those waves spread out and at last reach us, but our skin is not affected by them, though they touch it. Something else is affected, however. The outer ear has caught the waves, and its curves have made it easy for them to pass inwards along the little inside passage. Now these waves will break, at the rate of 300 times a second, on the membrane of the drum; it begins to vibrate, also at the rate of 300 times a second, and it makes the little hammer-bone vibrate, for, as you will remember, the handle of this bone is attached to the inner side of the drum membrane, the side of the middle ear. The hammer-bone being fastened to the anvil-bone makes it vibrate too, and the anvil-bone passes the vibrations on to the stirrup-bone, and the stirrup-bone, vibrating at exactly the same rate, faithfully carries on the message by knocking, or, more correctly, *vibrating*, against the little oval window leading into the inner ear. On the other side is the watery lymph, and instantly little waves run through the lymph at the rate of 300 times a second, up the *top* passage in the snail-shell (cochlea), through a tiny opening in the top to the lower passage. Down this passage go the waves hurrying to the vestibule at the bottom, and they die out by breaking against the little round window below the oval window which lies at the end of this passage. All the way up the snail-shell part of the inner ear they have been making the inner tube of soft membrane, which lies like a floor below them, vibrate strongly, and all the way down, when of course it lies above them like a ceiling, they make it vibrate also. Now, inside the membranous tube is the inner lymph (endolymph), and lying in it are the cells of hearing, with their delicate hairs. These hairs are at once set in movement by the tiny waves in the inner lymph, and by means of the fibres in touch with them the message of 300 vibrations a second is sent to the brain cells, who interpret them as a *sound*, the sound you heard when I struck the tuning-fork. Different notes have different numbers of vibrations a second, but the cells pick them out and send the right messages to the brain. The little semicircular canals of membrane inside the bony ones have clusters of cells connected with a branch of the nerve of hearing. These cells are stimulated by waves set up in the lymph when we move about, and from them we learn whether we

are standing upright or moving to one side, and so we are able to keep our balance. Therefore we see that the ear is not only for hearing, but is also the organ of balance.

We must not forget how we learnt that, in the floor of the middle ear, there is a tube going down into the throat lined with the same kind of mucous membrane as that in the throat itself. If the throat is sore and

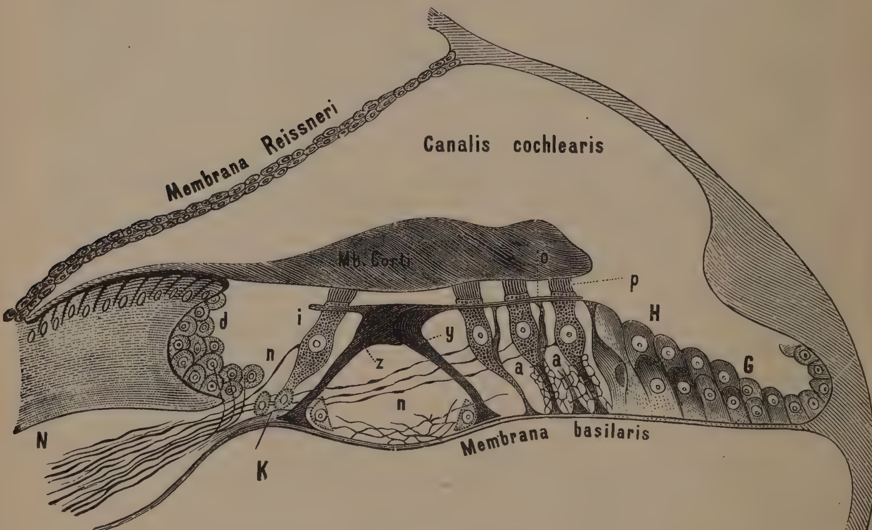


FIG. 66.—Corti's Organ.
mb, Corti's membrane. K, inner, P, outer hair cells. *n*, nerve fibrils coming from the brain and ending in P.

inflamed from a cold, the inflammation sometimes passes up this tube and enters the middle ear. Sometimes the inflammation so blocks up the tube that air cannot pass up from the throat. The consequence is that the air, which is already in the middle ear, becomes absorbed by the blood in the capillaries in the lining membrane. What happens then? Let us remember our lesson on air. Is the air in the passage of the outer ear pressing against it? Yes. At what pressure? At 15 lbs. to the square inch. Is it pressing at the same rate inside the ear when the throat tube is closed and the air in the drum is used up? No. What is the result? The air outside will press very hard on the membrane of the drum to try to get in and equalise the pressure; the result will be that the membrane becomes very hard and tight, so that it

cannot vibrate easily and set the little bones in motion and make them tap at the oval window and set the lymph in the inner ear moving, to tell the end cells: therefore the person is deaf on that side. This often happens with a bad cold. If we are standing near a big gun when it is fired off and are not protected by special ear-protectors, it is a good and wise plan if we swallow at the same time, for the air disturbed by the explosion of the gun presses suddenly very hard on the membrane of the drum from outside; and if we swallow, then air passes up the throat and the tube and by pressing hard on the inner side of the membrane helps to equalise the strain. A very big gun fired close to us might make us deaf if we did not stop our ears.

If people have constant colds and neglect them, they may become slightly deaf for the rest of their lives from the constant inflammation thickening the throat tube so much that air can only pass up with difficulty. Or sometimes the inflammation may pass into the middle ear and thicken the membrane of the drum so seriously that it cannot vibrate easily. Sometimes severe inflammation is set up in the middle ear and abscesses may arise, which may so injure the drum membrane that the person remains very deaf on that side or even becomes perfectly deaf in that particular ear. We ought never to neglect anything wrong with the ear, especially if there is a discharge from it. This is most important, as serious mischief may result.

Blows on the ear are dangerous things, as they may cause deafness for life by breaking the drum, and severe blows may even cause death. A box on the ear is a form of punishment long given up in schools because of the great harm it can do.

Deafness is sometimes caused by enlarged tonsils, and sometimes by growths called adenoids. This can be easily cured nowadays, but, as we want to talk about health and not about sickness, we shall not need to go into these questions here.

We must never be so silly as to put things in our ears, for they may be very difficult to get out again. If anything is pushed in by a stupid child, it is best to go straight to the doctor and get him to take the thing out for us. Considerable harm may be done by unskilled people trying to get the object out and only succeeding in pushing it further in. But now that we know what a wonderful and delicate thing the ear is, we are never likely to do anything so foolish.

Blackboard Summary.

1. The ear is in three parts: (1) The outer ear, consisting of the shell of the ear and a short passage leading inwards from it. (2) The middle ear or *drum* of the ear, shut off by a membrane, and having

three little bones stretching across it, and a passage in the floor leading to the throat. (3) The inner ear, consisting of a part shaped like a snail-shell, and three little tubes shaped like jug handles.

2. The outer ear catches the waves of sound and sends them to the middle ear.

3. The middle ear sends the waves on to the inner ear, and sets the lymph inside in motion, and the waves in this lymph touch the end cells, and they respond to the stimulus and send messages along fibres in the nerve of hearing up to the brain.

4. Great harm can be done by boxing the ears.

5. It is dangerous to put anything pointed into the ears to clean them, or to put any little thing in "just for fun."

CHAPTER XIX.

SPECIAL SENSES: TOUCH, TASTE, AND SMELL.

Necessary Apparatus.

A few small marbles.

A pair of dividers.

Accessory Apparatus.

Salt.

Acid, such as lemon juice.

Bitter aloes or quinine.

Sugar.

Pepper.

Small portions of fruit or vegetables.

Note.—Other things will no doubt suggest themselves to the teacher for experimentation as occasion may arise. For instance, ammonia and vinegar might be added to the above list.

As the amounts required are exceedingly small, they can all be arranged on one plate as far as the solids are concerned.

Among the sentinel, police, or scout cells who look after the welfare of the other citizen cells of the body are the important ones which find out about *smells*. In some animals it is very easy to see how the cord of nerve cells running through the body adapts itself to the power of finding out food by its smell. At that point these important cells grow in number till their end of the cord becomes much larger and forms the beginning of the big brain. For some animals it would be death to lose the sense of smell, as they would then be unable to know the whereabouts of their enemies until they were too close to be able to escape from them, nor could they smell out their own food. In man, the sense is not nearly so important, because he has learnt to use other senses more; nevertheless, it often saves his life. The smell of smoke has told many a man or woman of a house being on fire; the sense of smell has warned people that they were about to drink the wrong medicine; the sense of smell has spoken of hidden dangers from dirt or bad drains; and we can think of many ways in which these useful citizens have saved their own lives and those of everybody else in the citadel of the body, and perhaps in other bodies, by giving timely warning. It would be a great loss to us if we had no knowledge of the delicious scent of a rose and other flowers, besides many other pleasant and delightful perfumes, such as the smell of a summer morning, or the fragrance of a field of new-mown hay.

The organ of smell is the nose, and in the lesson on the lungs we learnt something about the nose and how important it was to breathe through it instead of the mouth, because the little hairs in the first part of it helped to keep out dust, and the damp mucous membrane inside caught and killed germs and moistened the air if it was too dry;

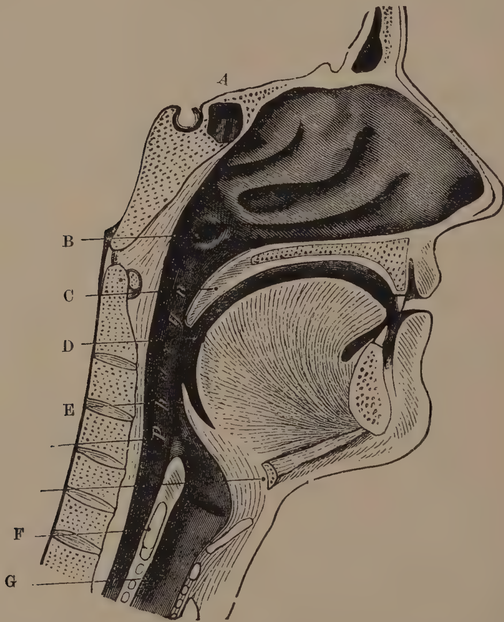


FIG. 67.—Vertical section through Nose, Mouth, and Pharynx.

A, ethmoid bone. B, eustachian tube. C, soft palate. D, tongue. E, epiglottis. F, gullet. G, windpipe.

and also the warm blood, circulating in great quantities of tiny blood-vessels in the membrane, warmed it; and thus it reached the lungs warmed, moistened, and purified.

The nose is divided into two nostrils by a division which is bone high up nearer the root and becomes gristle (cartilage) near the end, or rather about half way down. These nostrils open at the back into the upper part of the throat (pharynx) (see fig. 67). The hard palate forms, as it were, a floor to the nose, and its roof is the bone which separates nose and brain (ethmoid bone). We have already learnt that in

each nostril there are three little scroll-shaped bones padded with mucous membrane. The membrane in the lower part of the two passages is made up of cells with cilia, like those in the throat and lungs, and branches come to it from one of the twelve pairs of nerves which arise from the brain, the fifth cranial nerve. If we breathe in some strong irritating thing like ammonia (a thing which we must be careful never to do without knowing its strength, or it may choke us), the nerve endings are irritated by it and convey the message to the brain. But that is not the same as the sense of smell. The ends of the nerve of smell pierce through the roof of the nose and branch out in the upper part of the air-passages there, in connection with cells which have delicate hair-like threads coming from them. These are the end cells of the nerve of smell. In ordinary quiet breathing the air passes along the lower part of the air-passages and does not fill the upper part. If we are anxious to smell a thing particularly well we sniff the air in strongly and then it gets to the upper part and comes into closer touch with the end cells and stimulates them more strongly. If we have a bad cold in the head, we lose the sense of smell, because the mucous membrane becomes so thick and swollen by inflammation that the end cells are practically buried for the time. A dog's sense of smell is much keener than that of a man, but a man notices more with his eyes. If we walk along a strange road, we find our way back again by the memory of the sights we saw along it. It is probable that a dog remembers it better by the smells he met.

The sense of taste is partly connected with the sense of smell, as we can prove easily.

The tongue is the organ of taste, and is covered with little projections of horny cells called papillæ, of different shapes; some are roundish, others are long and slender. At the back of the tongue there are some quite large ones, each of which has a sort of ditch round it, making it look, under the microscope, rather like the castle we make on the seashore. In the sides of the ditches are special cells altered to form what are called taste-buds or taste-bulbs. In fact, these cells are arranged in little clusters rather like the bud of a flower. The sense-cells in the middle of the bud have slender, hair-like fibres coming out of them, and these wave about in the trench or ditch (II. E, fig. 68).

If we dry the tongue and put sugar or salt on it, we get no taste so long as we keep it dry, but if the salt or sugar melts, it runs into the little ditches surrounding the big papillæ at the back of the tongue (circumvallate papillæ), and then the cells in the taste-buds, having their fine hairs waving about in the liquid in the ditch, get a stimulus from the salt or sugar, and a sensation of what we call taste is sent up to the brain. Bitter things and sour things are detected by these cells.

Hot, burning things like pepper are felt by the touch-cells in the front of the tongue, but, apart from the burning sensation, the *flavour* of pepper is really known by the sense of smell. For example, the vapours from an onion pass to the back of the throat and up to the nose. That is why, if we have a bad cold in the nose, we lose our sense of flavour, which we confuse with the sense of taste; and then onions, and apples, and potatoes all seem to us much alike, for we lose their flavour completely, as it cannot reach the sense of smell. We can still tell, however, whether we are eating something bitter, or sweet, or salt, or sour, because these stimulate the taste-buds, as we have seen. We

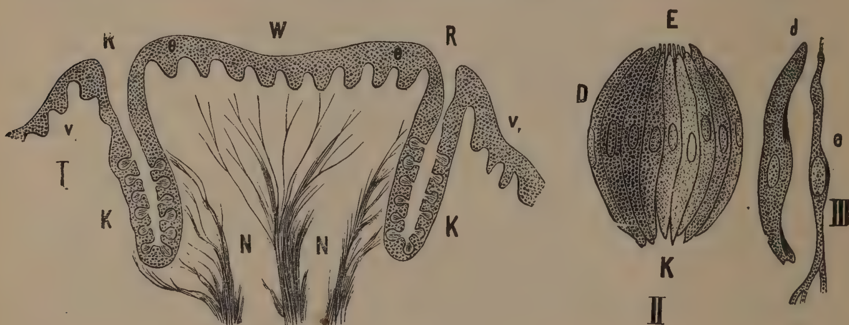


FIG. 68.

I., transverse section of a circumvallate papilla: W, papilla; KK, taste-bulbs in position; NN, nerves. II., isolated taste-bulb: E, free end, open, with projecting apices of taste-cells; K, lower end. III., isolated protective cell (*d*), with a taste-cell (*e*).

cannot tell, unless we see it, whether we are eating a sour lemon or a sour lime when we have a bad cold in the head, or whether we have been given a salt herring, or a salt anchovy, or a sweetmeat with a flavouring of raspberry, or one with a flavouring of pineapple: all we know is that we have eaten something sour, salt, or sweet. We can easily test this by having things of different flavours and tastes given to us while we shut our eyes and hold our nose. The sensation of touch in the tongue will help us to find out, simply because we know that certain things are smooth and others rough; but it is quite interesting to discover the difference between taste and flavour and to try to guess what is given to us. Of course, in this experiment no one would ever give a painful or dangerous thing.

Now we come to the last sense—the sense of *touch*, though it should really be called the first, since it was developed before any other. Even the little amœba has the sense of touch, though it cannot hear, or see

or taste, or smell. It shows us that all these wonderful powers of hearing and seeing, and so on, are only the sense of touch improved in different ways.

Now, the great organ of the sense of touch is in the skin all over the body, and in the mucous membrane inside, as for instance in nose and mouth. We remember that the skin is in two layers: the upper scarf skin (epidermis), consisting of cells, and the lower or true skin (dermis), containing sweat-glands, blood-vessels, and nerves. The skins do not lie evenly on the top of each other, for the lower one is thrown into ridges or waves (papillæ), and the upper skin dips down in between them.

FIG. 69.—Wagner's Touch-Corpuscle from Palm of Hand.

Many of the nerve-endings coming to the skin, end in a peculiar way; they penetrate into the projections or papillæ of the true skin and end sometimes as very small oval-shaped bodies, of whom it would take about 300 to form an inch, if put end to end. These little oval nerve-endings are made up of layers of fibrous tissue with a nerve fibre wound round and round them and finally diving into the middle of them. They are called *touch-bodies* (tactile corpuscles), and are found specially in the skin of our fingers and toes. They exist in great quantities on the skin of the front of the fingers. It has been calculated that about fifty can be found on the skin there in so small a space as $\frac{1}{25}$ of a square inch. Other touch-bodies are found on the edge of the lips and in the skin of the forearm and on the edges of the eyelids, but they are not in such great numbers. There are other nerve-endings also which are larger, some being about $\frac{1}{20}$ of an inch long.

These large nerve-endings are made up of layers of connective tissue over the end of the nerve. They are found in the palms of the hands and the soles of the feet, and near joints. Some nerves end in what are called "end bulbs," found in the lips; and yet other nerve fibres simply branch out and form a sort of network among the lower cells of the top skin. As we see, all the nerve-endings are protected by being buried below the surface, and have to be stimulated through the cells of the top skin.

Lay your hand on the desk in front of you. Tell me now what you are feeling. You feel that you are touching something? That is

also called the sense of contact. Do you feel anything else? Yes, the desk feels rather cold. Anything else? Yes, you can feel that you are pressing. This shows that the sense of touch is made up of three things—the sense of contact, the sense of heat or cold, and the sense of pressure.

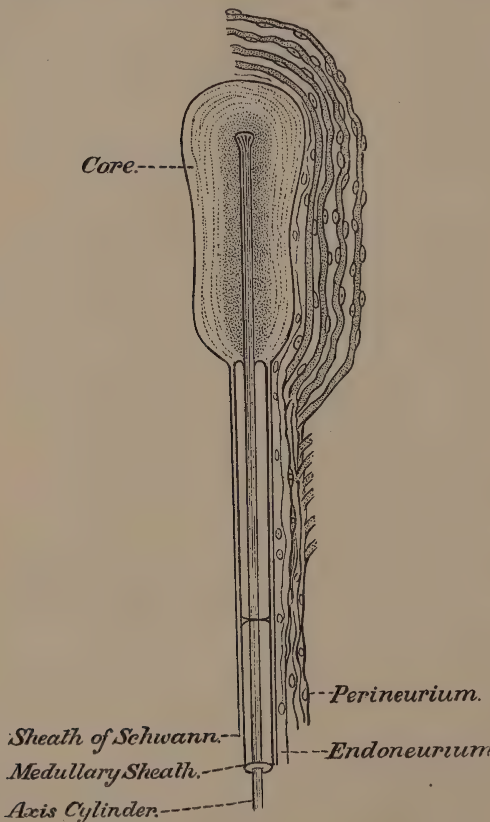


FIG. 70.—A Pacinian Corpuscle.

By the sense of contact we learn whether a thing is rough or smooth, and we find out about its size and shape by moving our hands over it, so as to touch a great many nerve-endings and send many messages to the brain. We also find out if it is hard or soft. Where do you think we shall feel most easily? Where the scarf skin is thick or where it is thin? Where it is thin. Yes; why? Because there is less covering over the sensitive nerve-endings. If you want to feel a thing very carefully and find out all you can about its smoothness or roughness, you feel with the inside of your fingers, where the true skin is very full of touch-bodies and the upper skin is thin, except in those people who do much hard work with their hands, for then the upper skin thickens in order to protect the delicate under skin. We sometimes put things to our lips to feel them, for the lips are very sensitive, and so is the tip of the tongue.

If we were to take a pair of dividers and either blunt the points

a little or fix tiny, sharp-pointed bits of cork on to them, to prevent them from pricking, we could make some interesting experiments on a person whose eyes are shut. We could open the compasses a very little way and rest them lightly on some part of the skin and ask the person if he felt two points or one. If it were not a sensitive part, the person would feel only one if the points were close together, but if there were a great number of nerve-endings in that place he might feel two points even when they were almost touching. The tip of the tongue can feel two points when they are only $\frac{1}{24}$ of an inch apart, whereas on the back of the hand they may have to be separated by more than half an inch before they are felt as two, and in the middle of the thigh they may have to be $2\frac{1}{2}$ inches from each other. This power of finding out where we are touched depends largely upon experience. We learn much by seeing, and grow to expect certain sensations, and we may be deceived if we get messages from different places which are not in the habit of coming at the same time. Here is a very small marble: put it on the palm of your left hand and roll it about between the first and second fingers of your right hand while your eyes are shut. How many marbles do you feel? Only one. Now cross your middle finger right over your first one so as to leave a good deep V-shaped space between the tops of the two fingers. Some people have very stiff fingers and do not get their middle finger far enough over, but you must mind and pull or push it well over, if you cannot do it naturally. Now, still keeping your eyes shut, get the marble in between the tips of those two crossed fingers and roll it about on the palm of your left hand. How many marbles are there? It feels exactly as if there were two! You can feel the end of your nose in the same way. What does it feel like? Exactly as if you had two ends to your nose. This curious result is because the brain is not accustomed to receive messages of one single undivided object from those two sides of the two fingers at the same time. It is accustomed to receiving them differently, and therefore gets the impression that there must be two objects.

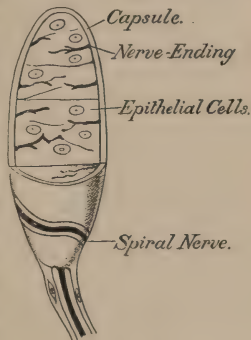


FIG. 71.
A Touch-Corpuscle, upper portion dissected.

We have learnt that we can also judge of heat and cold. This is called the *temperature sense*. It is not a very accurate sense, for if our hand is very warm and we put it into warm water, the water will not seem nearly so hot to us as it really is. There is a danger in this

if people forget it and are going to bathe a little baby; for if they feel the water with their hands and their hands happen to be warm, they may think the water only comfortable and nice for the child, whereas it is perhaps dangerously hot for so tender a creature. Of course, it is wiser in such a case to measure the heat of the water by a thermometer; but if we have not got one, then it is best to put the point of the elbow in, for that is a part which keeps a very even temperature. Some parts of our skin appear more sensitive to heat than others, and some appear more sensitive to cold.

The sense of pressure, which is the third thing we noticed, seems very like the sense of contact; but there is a difference, because some parts which are not good at these touch sensations are very good at judging amounts of pressure. When we put something in our hand and wish to judge how heavy it is, we move our hand up and down and feel in our muscles the amount of difficulty we have to raise the weight or prevent it from being lowered too quickly. This power has been called the *muscular sense.*

From all these things we learn something more about what a wonderful instrument the skin is. We learnt before that it was (1) a protective organ, (2) a purifier of the blood, (3) a heat regulator, and now we learn that it is one of our most important sense organs. We cannot imagine what we should be like if we could not feel. Sometimes we have been sitting in such a way as to cramp the blood supply to one of our feet and so to starve the nerves. Perhaps we do not realise it and get up and try to stand, but to our surprise our foot is quite numb and perhaps doubles up under us and makes us fall, because the nerves in the skin, where the foot was touching the ground, gave no message of pressure to the spinal cord and brain. We know how painful it is when our hand or foot has got numb or "asleep," as we say, for the blood pricks and tingles as it begins to creep back through the cramped parts, and we have a feeling which we describe as "pins and needles." Certainly we ought to take care of this wonderful organ, and keep it healthy and clean by fresh air, plenty of exercise and water, and by remembering that not getting rid of rubbish from inside the body will very quickly injure the skin. What a beautiful thing the skin of a well-groomed horse is! how bright and glossy it is, and how different it looks from the skin of a dirty, neglected, ill-treated animal! True, the horse's skin is covered with hair, but the hair is really a part of the skin; and if the skin is healthy, the hair which grows from it is likely to be healthy too.

Blackboard Summary.

1. The sense of smell is in the nose, where are situated the endings of the first pair of brain nerves, the nerves of smell.

2. The sense of taste is in the tongue, and salt, or sweet, and sour and bitter things have to be dissolved by the moisture of the mouth before they can be tasted.

3. Flavours are given off by some foods and stimulate the nerve of smell by passing up into the nose from the back of the throat.

4. The organ of touch is in the skin, which also feels heat, cold, and pressure.

5. A neglected skin cannot protect the body properly.

CHAPTER XX.

HAIR AND NAILS.

Necessary Apparatus.

A pine or fir cone.
A saucepan, with lid, containing some potatoes boiled in their skins. The skins should be well washed before boiling, and the water must be scrupulously clean. The potatoes should be cooked until quite soft, but, if possible, they should not be allowed to burst.
A spirit-lamp or Bunsen burner.
A sharp, clean knife.
A few cheap and small tumblers.
A few round glass slides or a few saucers:
A saucepan of boiling water on a stove.
Vaseline.
Pencils.
Labels.
Hand-lens.

Accessory Apparatus.

Microscope.

Note.—It must be understood that the simple precautions to kill and exclude micro-organisms given in this lesson are far from being perfect, and could not be depended upon for serious purposes. In this experiment there is no danger of cultivating disease germs, which, even if present, would not grow on potatoes prepared in this way.

A FINE head of hair is a possession of which anyone may be justly proud, be that person man or woman, boy or girl, and it is one of which care should be taken. What is the use of hair, and what citizens have formed it? Hair was originally a covering or protection for the body, and grows on the bodies of animals in such a way that rain is shed easily off it, and so it helps to keep the skin dry. Feathers, fur, and wool are all made from the same cells that compose the skin, just as hair is. Some of these outer coverings are full of oily matter which keeps out damp. Sheep's wool has a great deal of grease in it; the feathers of ducks grow so closely together and are so full of oil that a duck can dive under the water without getting its skin wet, for the water merely runs off. Mankind, having learnt to wear clothes made from the skin, hair, wool, fur, and feathers of other animals, has no

longer the need of growing a covering of his own, and has lost the power. We hope that the wearing of hats will not cause the hair of the head to disappear too. Hairs are formed from the top or scarf skin, which dips down in a little hollow or "sac." The lower part of this "sac" rests on the true skin, which pushes up into the bottom of the sac with a cluster of capillary blood-vessels (see fig. 48, p. 81). As the cells in the bottom of the sac are so near the blood, they get plenty of food and begin to grow rapidly and to divide, and the lower ones, which are the latest comers, push the upper ones before them until they form a slender rod, whose top appears at the level of the surface of the skin, and the hair may continue growing from the bottom until it is many inches long. The part where it started at the bottom of the sac is thicker than the rest and is the root of the hair. The sac forms a sheath round the hair, and this sheath is known as the hair follicle. Into the sacs open passages from tiny glands (sebaceous glands) (see fig. 48, T), whose cells make a delicate, oily matter called sebum, which is the natural oil of the hair. The hair is therefore a solid rod, made of cells. The cells are not quite so close together in the middle, so that when we look at a hair under the microscope it often looks as if it were hollow in the centre, as it is lighter there. The cells overlap each other on the outside, rather like the scales of a soft pine cone. If we pull a hair out of our head and hold it by its middle between finger and thumb, rolling it for a little time as we do so, we shall see that one end gradually moves further and further away from the fingers, and presently the hair will move right out and fall on the ground. The end which moves away is always the root end, for in rolling we are pressing against the edges of the overlapping cells and so are pushing the hair away. If the skin on our fingers is sensitive, we can also feel which is the root end by holding the hair, first at one end and then at the other, and pulling it slowly through our fingers. It will feel slightly less smooth one way, and that way will always be towards the root, on account again of the overlapping cells.

The skin of the head, and the hair itself, need to be kept clean by brushing and washing. There are few things more disgusting than dirty heads, and no one who respects himself or herself will ever allow the head to be infested by parasites. If people are in danger of this annoyance it may be necessary to use a fine comb, but otherwise such combs are bad for the hair, for they break it and irritate the scalp. Little invisible cells which cause mould in other things often do much harm to the neglected head, for they get down into the little hair-sac and injure the roots of the hair and help to cause dandruff. On account of this, we ought to be careful to brush our hair well with a brush which is kept very clean, and, if the hair is long, to wash it once a

fortnight or once every three weeks. Careful brushing of the hair draws out the natural oil from the little oil glands near the root and makes the hair look bright and glossy. With very dry hair it may be necessary to use some preparation of a slightly oily nature in order to replace the natural oil. Careful brushing of the hair not only stimulates the oil glands, but it brings more blood to the roots, and therefore the hair grows better and is better nourished.

The nails of our fingers and toes are made up of citizen cells from the skin, which have hardened themselves to protect these much-used parts. A groove forms in the skin, and is known as the nail-bed.

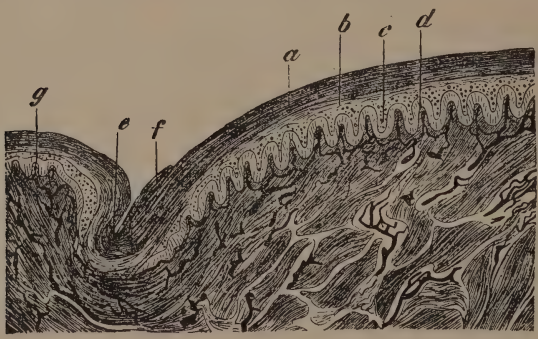


Fig. 72.—Transverse section of One-half of a Nail.

a, nail substance. *b*, more open layer of cells of the nail-bed. *c*, stratum Malpighii of the nail-bed. *d*, transversely divided ridges. *e*, nail-groove. *f*, horny layer of *e* projecting over the nail. *g*, papillæ of the skin on the back of the finger.

From this the altered cells grow upwards to form the nail. Nails should never be bitten, for that is an ugly and deforming habit, which ruins the shape of the nail and the finger-ends. Nails should be cut with scissors, and, if kept reasonably short, should keep clean without the need of a brush, if we begin the habit early enough of washing them in such a way that we do not interfere with Nature's plan of moulding the nail so closely to the end of the fingers that it is difficult for dirt to get in. The wet and well-soaped hands should be clasped over each other so that the fingers of each hand are in the palm of the other. Then the tips of the fingers are moved vigorously about for a few seconds in the soapy water inside the hollow of the palms. This should suffice to clean them. Scraping the dirt away with a knife is a very bad plan, for the knife separates the nail from the finger end and forms a hollow in which dirt easily collects. A brush does much

less harm, and is necessary in most cases. While the fingers are still wet after washing, the skin round the base of the nail is soft, and that is the time while we are drying our hand to push this skin down from growing over the nail. Sometimes it grows so much that it hides the white half-moon at the base of the nail, and that should never be allowed. Dirty, ragged, bitten, untidy finger-nails betray that their owner is a sloven. There is a very common idea that the finger-nail is poisonous. It is not poisonous in itself, but becomes so by reason of the dirt under it, which very often contains mischievous germs which may cause much trouble if they get into a wound. There is no doubt that, if people kept their nails clean and short and always washed their hands before they ate, there would be far fewer cases of illness in the world.

Now we will try a little experiment. Some of you can do it for yourselves. Here in this saucepan are some potatoes which have been boiled with their skins on, and are now quite cold and are still under the water. Boiling will have destroyed most, if not all, of the little invisible germ cells which are clinging to everything, and are so tiny that it would take thousands of some of them, put end to end, to form an inch. Many of these germs are our friends, but some are our foes, and there are many different kinds of them. Everything that rots and decays does so because a germ cell has acted upon it and has pulled it to pieces. No germs can enter the unbroken skin, and even if the skin is broken the healthy body cells fight and kill them, unless they are so many that the white blood cells which do the fighting get overpowered. Germs can also be swallowed, but again the healthy gastric juice of the stomach can generally kill them. We need not be always in fear of germs if we lead clean, sensible lives in clean surroundings and in pure air, but it is never wise to give them a chance to stay on our bodies, for we never know when they may find an opportunity of getting in and perhaps doing us an injury. Some germs form little seeds (spores), which are very hard to kill, but probably there were none of that kind on the potatoes or in the clean water we used. I have kept the lid on the saucepan as long as possible, in order not to let germs fall in from the air. Here are two or three common drinking-glasses, which have been well washed and ever since have been standing mouth downwards to prevent germs from entering. Here in this dish are a few round pieces of ground glass, which have been well washed and are now in weak disinfectant and water, so that no germs can settle on them. If I had not these slides I would use saucers, but they are not quite so convenient. Now I will light the spirit-lamp (or Bunsen burner) and ask one of you to come and stand beside me and lift the lid off the saucepan, not taking it right away, but holding it a

little way up as a shelter over the pot, leaving me just enough room to get my hands in. Germs, in quiet room air, are mostly falling straight downwards, so our saucepan lid, held like a shield over the pan, will prevent any from touching the potatoes. Here is a very sharp, clean knife, and to make sure that there are no germs on it I will pass it quickly two or three times through the flame. Now I will hold a potato *under the shelter of the lid*, in my left hand, and with the knife in my right I will cut off the skin from one part and cut out a little flat thickish slice of the clean white potato, taking the utmost care that my fingers do not touch it. The fingers of my left hand touch only the skin of the potato, and the knife only cuts through the skin where my fingers have never touched it, and I never allow the knife after that to touch the outside of the skin but keep it cutting away underneath. Now bring the bowl with the glass plates in it as close to the pan as you can, and lift one of the plates out by its edge, using a pair of pincers. Hold it edge upwards to prevent germs from settling on it, and bring it quickly under the shelter of the lid close to where I am cutting the potato, and then turn it flat. Now I will place the little slice of potato on it, and someone else must take one of the little glass tumblers and, holding it mouth downwards, plunge its edge quickly into the pan of boiling water on the stove. This is to destroy any germs which have got on to the edge from the place it was standing on. *Keep it mouth downwards*, but hold it, and quickly put it over the glass slide and the little slice of potato. Do this, if you can, under the shelter of the lid of the potato-pan. Now I will put the cover over the potatoes until we want another slice, and meanwhile you are holding the glass slide, and you know that there are no germs on the potato, no germs under the tumbler, and certainly no germs on that part of the slide which is under it. We will now smear a little vaseline round the outside edge of the tumbler to keep out the air and prevent any possibility of other germs getting in. This potato, therefore, ought not to go bad, since we have learnt that it is germs which cause decay. It ought only to dry up. We will put a label on it, and write on the label "Control test." Now we will prepare another slice in exactly the same way, but as soon as we have got it safely under the shelter of the tumbler we will look round and see who has got dirty nails.

I hope that all of you have got clean nails, but perhaps we can collect a little dirt and scrape it out with a knife; only, we must be quite sure that there are no other germs on the knife than those it may get from the dirt, so we will pass it two or three times through the flame of the lamp or burner first. Now that I have a little dirt collected and on the knife, we will lift up the second tumbler from off

the slice of potato, but not higher than half an inch, and we will slip the knife in and very thoroughly smear the dirt well down on to the surface of the slice of potato. We had better prepare two or three more of these little slices and label each one with the initials of the person who prepared it. We will put them all away in a dark *warm* place for about a week and see what happens.

. . . .

Now we will examine the potato slices which we prepared the other day. Here is the one we labelled "Control test." Let us look through the glass and see if there is any change. No, none at all apparently! The potato looks just as it did when we put it under the glass days ago. Here are the others prepared in just the same way, so they ought to look just the same, unless a germ got in with the dirt we put in afterwards. Let us look at this specimen which I smeared with the dirt from under the dirtiest nails in the room. Can you see any difference? Yes, a great difference; the potato has changed colour in one place, and a dirty, greyish-black, and nasty, decaying, mouldy matter is growing on it. That nasty matter is made by germs which have begun to grow in the potato, and have formed a big colony of themselves which you can actually *see*. They have destroyed the potato by growing on it, and are rapidly altering it and making it "go bad," as we say. As the control test is quite sound and undecayed, it is obvious that it must have been the dirt which we put in that contained the germs which are working here. Now we will look at all the other experiments. Some may be worse and some much better than others, but it is quite evident that a so-called poisonous nail is a dirty one, with germs under it. It is the dirt and germs and not the nail which are poisonous. We will certainly be careful of our nails in future and see that we keep them short and clean.

Blackboard Summary.

1. The hair must be kept very clean and be well brushed with a clean brush. Brushing not only cleans, but it brings blood to the roots and nourishes them and draws out the natural hair oil which makes the hair bright and glossy.

2. Nails should be kept rather short and no dirt allowed to remain under them. They may be cleaned with a brush, but not with a knife, and should be cut with scissors, or filed, but never bitten.

3. Dirt under the nail probably contains germs.

4. Hands should be washed before meals.

A FEW SIMPLE RULES AND THEIR REASONS.

Rules.	Reasons Why.
Never spit on the floor	You leave germs for others.
Keep your nails short and clean . .	No germs under them.
Do not put your fingers in your mouth .	Germs are on dirty fingers,
Use your tooth-brush well, especially at night.	You get rid of germs and the food they feed on.
Do not wet your finger or thumb to turn over leaves of books.	You pick up germs from the paper and leave germs for others.
Do not put into your mouth anything that anyone else has had in his or hers.	You get their germs.
Hold your hand before your mouth when you cough or sneeze, and turn your head away, and expect others to do the same.	Coughing and sneezing send germs out into the air.
Be very clean in skin, clothing, hair, teeth, and nails.	You keep germs away.
Always wash your hands before you sit down to a meal.	You get rid of germs.
Breathe through your nose . . .	Mouth-breathers take germs into mouth and lungs: nose-breathers keep them out.

PART II.—FOOD AND CLOTHING.

CHAPTER XXI.

ELEMENTS AND PROXIMATE PRINCIPLES OF FOOD.

Necessary Apparatus.

Test-tubes.
Rack or cup to stand the tubes in.
Spirit-lamp or Bunsen burner.
A small piece of clean muslin.
A dessert-spoonful of flour.
A bowl.
Tincture of iodine. Use one drop, or else mix a few drops with water to a light sherry colour and use freely.
Two or three grapes. Raisins will do if a little water is added.
A small glass funnel.
A piece of filter paper.
A little clean water.
Bottle of 10 per cent. potash solution.
Bottle of 1 per cent. copper sulphate solution.
A bottle of methylated ether (cheaper than pure ether).
Bottle of Millon's reagent.[1]
A wedge of raw, peeled potato.

Accessory Apparatus.

Mount a few grains of starch, raw and cooked, separately, in water under the microscope.
Leguminous plant, showing tubercles on roots.

To-day we are going to begin to learn about one of the most wonderful things that the body does. We have learnt how the citizen cells build up a strong, bony framework for the body; how the muscle cells make themselves into labourers to move the bones about on the joints and enable the legs to walk, and the arms to move and do all kinds of work. We have seen how the heart cells have made it their business to

[1] Dissolve mercury in its own *weight* of strong nitric acid. Then dilute the solution with twice its *volume* of water. Decant the clear liquid. This is Millon's reagent. The chemist will prepare it for you quite cheaply.

pump nourishing blood all round the body, and how other cells have made themselves into pipes to carry it. We have also seen how some cells have become the means of taking in fresh air and sending it into the blood for all the cells to use, and we have learnt how the skin helps the blood to keep pure and at the right heat. We know also that other cells have made themselves into teeth to crush up food for the body, but, except for the teeth, we have not yet learned how the food is prepared in such a way that it can be used by all the cells.

We learnt, in the first lesson of all, how the little one-celled animal gets its food. It is the same with us. The great difference is that the one-celled animal has a very simple task to do, but the many-celled animal has a very difficult one.

If one house stands alone, it is easy to get air and light and water to it and take away rubbish ; but if there are thousands and thousands of houses standing together, and some are colleges, some are palaces, some are law-courts, some are churches and chapels, some are railway stations, some are stables, and others are shops and factories, mills and private houses, and if sheep, and oxen, and fowls, and fruit, and vegetables, and corn, and water are all far away, then it becomes a very different matter to get food up to them. Pipes must be laid to bring water into the heart of the town, and other pipes to take dirty and waste matter far away out of it. Farmers and manufacturers and shopkeepers will have to supply food for the inhabitants. Engineers will have to make roads on which to convey the food, and some will have to be macadamised roads, and some will have to be railroads. Carts and motor cars and trains will have to be made to carry the food, and men will have to learn to drive them. Builders and bricklayers will erect houses and keep them in order after the architects have designed them. Gas and electricity will be manufactured by gasmen and electrical engineers to light the streets and buildings after the other engineers, and the builders, bricklayers, etc., have done their share. Miners will dig coal out of mines to provide fuel for warmth and cooking and for making the gas. Post and telegraph offices will be established and wires put up to carry messages all over the town as quickly as possible. There will be a busy host of people keeping the place in good order, so that the inhabitants can all get food and warmth, light and shelter, move about easily from place to place, gets news quickly, and, moreover, keep clean and healthy.

Just as it is evident that in a town everyone must do his or her share of the work necessary to keep things going well, so also is it in our bodies, and one of the most important things is the preparation of food and its distribution. It is all very well to see a beautiful field of wheat, but the hungry person in the midst of a great town

has to have that wheat brought to him and prepared in such a way that he can eat it. Therefore there must be harvesters to cut the corn, and manufacturers to make the machinery to help the harvesters, and also carters to cart and carry the corn. There must also be people to make the carts and the trains which carry the corn, and there must be mills to grind it into flour, and when it reaches the towns there must be bakers to bake it and vans to distribute it, until at last the field of corn reaches the houses in the form of loaves of bread. Just as the citizens in a town cannot eat the corn until it has been prepared, so the citizens of the body cannot eat even the prepared corn in the shape of bread until it has been prepared again for them and made into a form so delicate that it can be used by the innermost cell of the brain and by the innermost cells in the bones, as well as by every other cell in the body.

We will begin by finding out what kind of food is needed. In our first lesson we learnt that our bodies are made up of certain elements, and that Nature has large storehouses in which she puts these precious elements. The beings who open the storehouses and take out the elements are the plants, for it is only they who can unlock the doors. It is a wonderful thing that our very life is dependent upon the grass of the field. One of Nature's storehouses is the air, and another is the soil. In these two she keeps the food for all the millions of animals and plants who live on the soil and in it, but she has a third storehouse in water. She feeds all life and never wastes a single thing. How does she do it?

The body is made up of about thirteen elements,[1] and four of the most important of them are carbon, hydrogen, oxygen, and nitrogen. Some of the elements are gases, and are quite invisible to us when they are alone, and also sometimes when they are together. If our bodies were burnt and destroyed entirely, the elements would remain, for they cannot be destroyed. The great storehouse of the element carbon is the air. Do you remember our lesson on air, and about the gas called carbon dioxide? Do you recollect that it is a compound of oxygen and carbon? One part of carbon to two parts of oxygen (CO_2)? Our bodies are largely made up of this carbon, and it all comes out of the air. The nitrogen of our bodies comes from the air and from the soil, and the oxygen from air and from water, and the hydrogen also from water. We get the hydrogen and part of the oxygen in a combined form, for we get it in the form of water, which is composed of these two gases in the proportion of two parts of hydrogen to one of oxygen (H_2O).

[1] Actually 19 may be present: carbon, hydrogen, nitrogen, oxygen, sulphur, phosphorus, fluorine, chlorine, iodine, silicon, sodium, potassium, calcium, magnesium, lithium, iron, and sometimes manganese, copper, and lead.

No child can grow unless it gets these elements, for they are the very bricks of which the house of life is built, and you and I would soon fade away and die if we did not get them, for we are always using up our bodies. We cannot move a finger or think a single thought without part of our bodies wearing away and having to be replaced by fresh, good, pure material of the same kind, and it is the plants that get it for us. We will choose wheat as an example. First the seed is sown, and then a tiny green plant springs up. That green blade is growing because it gets food out of Nature's storehouses. It breathes in carbon dioxide gas and splits it up into carbon and oxygen. It sends the oxygen out again into the air and keeps the carbon, building it up with hydrogen and oxygen, which it gets in the form of water. With these three things, arranged in a certain way, it makes a kind of material called a carbohydrate. This kind of thing, built up by living organisms, is called, when found in the animal body, a *proximate principle.* It is built up, as we see, of elements which we do not find free by themselves in living things except in very small quantities. The name given is one that signifies that in this substance we have got as near to the elements as we can in the living organism.

Plants can build up carbon, hydrogen and oxygen, into more than one form. One of the forms that carbohydrate takes is *starch.* Here is some flour made by grinding up a few grains of wheat. The seed of any plant always contains a large amount of food material, for it has to provide food for the young plant as it sprouts, before it is able to find food for itself out of air and soil. I will put this flour into this little muslin bag, and knead it well under the water in this bowl. See! A quantity of white stuff comes out and passes into the water, and now I seem to have got out nearly all the white stuff, and only a queer, sticky, yellowish mass remains behind in the bag.

Now I will take some of the water in the bowl and put it into a test-tube and boil it, and then let it cool. In this bottle I have some very weak iodine and water. I will pour some of it into the test-tube. What happens? The water which contained the white stuff has turned a deep blue. Now I will heat the test-tube carefully in the flame of this spirit-lamp (or Bunsen burner). What happens? The blue has faded nearly all away. I will allow the tube to cool. What has happened? The blue has come back, but if I had heated it until the colour had quite gone, the deep blue would not have come back. This blue is a sign that a carbohydrate is present and in the form of starch, and the proof is complete if the colour disappears on heating and reappears on cooling. If I use baked flour, the colour will be much stronger, because starch is contained in little grains whose covering bursts on being heated, and the iodine can act on it more easily.

What have we learnt from this experiment?

We have learnt that wheat grains manufacture starch, and we know that they make it out of air and water, a thing which we cannot do for ourselves. But plants can make other things out of carbon. They can make another kind of carbohydrate. Here are two or three grapes. I will crush them up and strain off the juice and pour it through clean white blotting paper or filter paper, taking care to wet the filter paper first with clean water, or else the dry paper will soak up the whole of our grape juice and none will filter through. We will now take the few drops which have passed through and put one or two into this test-tube with a drop or two of water—one cubic centimetre is enough. Here I have two bottles (Trommer's test): one contains a 10 per cent. solution of potash; this other with the faint blue liquid in it is copper sulphate (1 per cent.). I will pour into the test-tube some of the potash, and then add a few drops of the copper solution and shake it up. What happens? The liquid has turned blue. Now I will warm the blue solution in the flame. What happens? The blue colour disappears. Anything else? Yes, a yellow colour appears and turns to red. The tube seems full of fine red sand falling to the bottom. (Red precipitate of cuprous oxide formed, which may possibly be yellow at first.) Now, this is a test for grape-sugar, and the red precipitate shows that it is present. We can get the same result if we experiment with other fruits than grapes. What have we learnt from this experiment? That fruits contain sugar. What do they make this sugar out of? Out of carbon dioxide and oxygen and hydrogen. Can you think of other plants besides fruits that make sugar? Yes, the sugar-cane and the sugar-beet. But if we want to test this latter kind of sugar we should have to boil it for a long time first and turn it into two different kinds of sugar. Turning cane-sugar into the kind known as grape- or fruit-sugar is called "inverting" it, and starch can be turned into sugar by treating it with an acid. Much of the sugar used in making jam is "invert" sugar.

Yet again, plants make something else out of the carbon dioxide of the air, for they build the carbon up in a different way with hydrogen and oxygen and make it into the proximate principles known as hydro-carbons, or fats and oils. We could find a little trace of oil in wheat-flour if we tested it. Can you think of any plant that makes a lot of oil? The olive tree with its olives. Yes. Nuts also contain much oil. Oil is also made out of the seed of the cotton plant, which contains a large amount, as also does linseed.

I will shake up a little whole-meal flour in a test-tube with a little ether and then pour it out on to this piece of filter paper. If there is any oil in the flour, there will be a trace of it when the ether dries off, which it does at once. We must take care *never* to bring ether any-

where near a flame, for it catches fire very quickly from the vapour which comes off it, and we might have a nasty accident. Can you see anything on the filter paper? There is a very faint, greasy line where the ether was. That shows that there is a little fat or oily matter in flour, but it is a very small quantity.

Both these kinds of foods, carbohydrates and fats and oils, or *hydrocarbons* as they are also called, have carbon as their principal element, and so we often talk of them both as *carbonaceous* foods A carbonaceous food, then, may be starch, or sugar, or a fat or oil. These foods when eaten give heat and energy to the body.

There is another important element we have mentioned, and that is nitrogen. The air is made up largely of nitrogen, but, though we breathe it in, we breathe it nearly all out again, and we should starve for want of it if it were not for our friends the plants. They can get it out of Nature's storehouses of the air and soil, and build it up with the carbon, hydrogen, and oxygen, and with also a little sulphur and phosphorus, to form a most important material called proteid. Proteids are a third form of proximate principle.

Proteids are divided up into several divisions, and it is rather puzzling for people who are not going to study them deeply, when they hear of *albumens*, *gelatins*, and *proteins*, etc. We will not go into all these, but we will remember that they all have one thing in common, and that is that they all have the element *nitrogen* in them, and on that account they are talked of as *nitrogenous* foods. The proteids made by plants are of different kinds. In wheat it is called *gluten.*

Here in this muslin bag I have a sticky mass which was left behind after I washed away the starch from the rest of the flour. I will put some of this into a test-tube, though it is very difficult to get it in properly, as it is so very sticky, or *glutinous*, as we say. I will add a little of this liquid (Millon's reagent), and boil. What happens? It turns brick red. When a substance is treated with this particular reagent and turns this colour it is a sign that a proteid is present. So we have learnt from this experiment that the wheat plant, at all events, is a plant that can make a proteid ; but so can other plants, and we know that they make them out of the air and the soil. Peas and beans make a quantity of proteid, and they are very clever at getting nitrogen out of the air. The proteid they make is called *legumen.* Plants which make legumen are called *leguminous* plants.

Here is a vetch which I pulled up very gently out of soft ground in the hedge, so that I got all its roots up with it. It is a leguminous plant. Look at the roots: do you see anything peculiar about them? Yes, they have tiny lumps on them, some not larger than a pin's head, and looking rather like fairy potatoes. In these little lumps,

which are called tubercles, live germs (bacteria), friends of the vetch, which help it to get nitrogen out of the air and make it grow fine and strong. Here is another vetch which has no tubercles on its roots, for it has found no such friends, and it is not nearly so well grown and strong. Foods with nitrogen in them are for the building of the body.

Plants also store up something else. Here is a slice of raw potato in a test-tube. I will heat it gently over the flame. What happens? Vapour comes out of the test-tube. I will hold a cold glass or plate against the vapour. What happens? Drops of water form on the glass. Where has the water come from? From the potato. All plants store up water. A turnip, though it seems so solid, has more water in it in proportion to its solids than a glass of milk. Water is for the fluids of the body.

We can also burn away this flour on a red-hot iron plate or shovel, and finally have nothing left but certain salts, and these salts are proximate principles just as the water also is, and help to build the body. Vegetables store very useful salts—salts of potash and salts of sodium; and some plants hold iron, of which spinach is one. The salts found in plants are very necessary for men and animals. We realise now what a wonderful work plants do for us. They purify the air; they dry the soil by drawing up water; they open for us the great storehouses of Nature, and, taking out of them the elements carbon, hydrogen, oxygen, and nitrogen in very simple compound forms, they prepare and build them up into the five proximate principles, the only form in which we can deal with them.

		Proximate principles.	*Made of the elements—*
(1)	Organic.	Carbohydrates (starch and sugar)	Carbon, hydrogen, and oxygen.
(2)		Hydrocarbons (fats and oils)	Carbon, hydrogen, and oxygen.
(3)		Proteids (gluten, legumen, etc.)	Carbon, hydrogen, oxygen, and nitrogen.
(4)	Inorganic.	Mineral salts (phosphate of lime, phosphate of potash, phosphate of magnesium, chloride of sodium, etc., etc., etc.)	Phosphorus, calcium, potassium, magnesium, sodium, chlorine, fluorine, sulphur, iron, etc.
(5)		Water	Hydrogen and Oxygen.

These proximate principles are, then, the only forms in which men and animals can get the elements out of which their bodies are built, and by which they are warmed and do their work. Sometimes we get them straight from the plants, as when we eat potatoes or bread. Sometimes we let the sheep and cows eat the plants first and build the proximate principles in them up into their own bodies, and then we eat the sheep in the form, perhaps, of a mutton chop. But the flesh of the sheep has come from grass, and the grass has come from the air and soil. Therefore without the work of our humble brothers and sisters the

grass and flowers of the field, and of the plants that live in the waters, all men and animals would die.

Let us now put on the blackboard some of the things which we have learnt:—

Blackboard Summary.

1. Our bodies are made up of about thirteen elements which cannot be destroyed. Four of the most important are carbon, hydrogen, oxygen, and nitrogen. These are found in air, soil, and water.

2. Men and animals cannot live on these elements, nor even on the very simple compounds, but plants can do so.

3. Plants build these elements up and make them into carbonaceous and nitrogenous foods.

4. Carbonaceous foods have carbon as their principal element, and are divided into carbohydrates and hydrocarbons.

5. Carbohydrates are starches and sugars, made up of the elements carbon, hydrogen, and oxygen.

6. Hydrocarbons are fats and oils, made up also of carbon, hydrogen, and oxygen, but arranged in a different manner.

7. Nitrogenous foods are proteids such as the gluten of wheat. They are made up of carbon, hydrogen, oxygen, and nitrogen.

8. Water and salts are also stored up by plants.

9. Plants get their food from air, soil, and water. Men and animals get theirs by living on plants and on other animals.

10. The five proximate principles of the body which are either made by plants or stored up by them are, therefore: carbohydrates, hydrocarbons, proteids, water, and mineral salts. Our bodies are made up of such substances.

CHAPTER XXII.

FOOD AND DIGESTION.

Necessary Apparatus.

A small piece of candle.
Matches.
One or two dry glass tumblers.
Limewater.
Some cornflour.
Two pieces of bladder.
Some packing thread.
Sugar.
Iodine.
Test-tubes.
Bread. *N.B.*—The bread can be put ready in the test-tube after having been held in the mouth to allow the saliva to act upon it.
Potash solution, 10 per cent.
Copper sulphate solution, 1 per cent.

Accessory Apparatus.

Good diagrams.
Microscopic slides of sections of liver, etc.
Microscope.
A small piece of tripe to show the absorbing surface of the intestine of an animal, and how villi increase it.

Have you ever been into a station-yard? Perhaps, if you have, you may have seen a beautiful new engine, complete in all its parts and a picture of strength. But that engine is doing no work. Perhaps you also see a great mass of coal lying in the yard. Presently some of that coal is put into the furnace of the engine, and the fire is lit. Water which has been placed in the boiler is now heated, and steam is raised under pressure. This pressure of the steam is so great that it can send the engine forward along the lines, and give it *energy* to travel for many miles and to draw great loads of goods and carry many passengers to their destinations. The engine was helpless without the coal, and, though the coal had power and energy locked up in it, it did none of all that work of conveying goods and people until it was burnt in the furnace under certain conditions and then it gave power to move the wheels.

But as the engine does work, it wears away, and perhaps an engineer

has to be called in to *repair* it. If he repaired it with wood it would no longer be the same kind of engine. He must use brass, and steel, and iron, and make it as strong as it was before. The human body has very often been compared with an engine. It may be beautifully made, but it cannot do its work unless it has that in it which will give it *power*. The coal in the station-yard is a rough kind of carbon. The food we need to give us energy is also carbon. We have already learnt that when carbon joins on to oxygen, *heat* is given off. Now, the coal in the engine is joining on very quickly with oxygen, and making a fierce heat. The heat has to be regulated by the engine-driver and the stoker. The carbon needed by our bodies unites with oxygen, but more slowly, and keeps us warm. But although in our bodies the union is slow, yet we might easily get overheated. Do you remember which cells help to regulate the heat? Yes, the cells of the sweat-glands in the skin. That was one of the duties of the skin, you remember—the regulation of the heat of the blood.

Materials like coal and wood, which we use in making fires, we call by the general name of *fuel*. Where does the body get its fuel food from? From the carbon of plants, and also from animals which have eaten plants. We remember that these fuel foods are starches, sugars, fats and oils. Here is a little piece of candle. The wax of the candle is a hydrocarbon. I will light the candle and hold this clean, dry tumbler over it for a minute while the flame burns. Now let us quickly look at the tumbler. Is it still clean and dry? No; inside, the top is black with smoke and the sides have a little mist of moisture on them. Now we will pour in a very little limewater and shake it up with the air in the tumbler. What happens? The lime-water turns milky. Of what is that a sign? Of the presence of carbon dioxide. The carbon of the wax has burned away—in other words, it has joined on or *united* with oxygen, and forming the compound gas, carbon dioxide, has passed into the storehouse of the atmosphere. Some of the hydrogen of the wax has joined with oxygen to form water, and the smoke is carbon which has not got completely burned, for it has not been able to get enough oxygen to turn itself into gas. So we see that when we burn a *fatty* or *oily* matter, containing carbon, hydrogen, and oxygen, it may leave behind it water and carbon dioxide gas. Coal is also composed of the same elements, and as in the case of the fats and oils its principal element is carbon, so also when it burns away it leaves the same substances behind it. When coal burns, however, *ashes* also are left behind, for it is a less pure form of carbon than the wax of the candle. The carbon dioxide is not lost, the plants will get it again out of the air. The water and the cinders are not lost either. Nature can use them all.

Foods, then, with carbon in them are "body warmers," and the heat made by them can be turned into *energy* or *power to do work*.

We saw that as the engine worked it was worn away; so also is the body. But the latter mends itself, it needs no engineer. The body takes in food which will build up the parts which wear away. That building material is a proteid. We know that proteids contain nitrogen, which is necessary in building up flesh and blood. So we eat the proteid called *gluten* which is found in wheat; the one found in peas and beans and known as *legumen*; that one, also, called *casein*, in milk; and the proteid called *albumen*, such as is found in white of egg, and the proteids in the flesh of animals. These foods are called "body formers" Another body former is water, for over two-thirds of our bodies are made of it. In one of the big museums of London there are arranged a series of jars showing the proximate principles that would be present in the body of a man weighing 150 lbs. In one jar, a big one, are 91 lbs. of water, in another 27 lbs. of proteids, another has 21 lbs. of fat, and a tiny one has 3 ounces of sugar and starch. Then there are some mineral salts, of which the most abundant are 8 lbs. of phosphate of lime and 1 lb. of carbonate of lime; there is also a little sulphur, and enough iron to make two or three small tacks. So we see that water is a very important part of the body.

We can now divide the materials of food into two kinds :—

Body Warmers.	*Body Formers.*
Proteids.	Proteids.
Carbohydrates.	Mineral matters.
Fats.	Water.

Which of these foods can both warm the body and build the body? Proteids. Yes, proteid food is the only kind capable of doing both, and that is a reason for its great importance. We could live on proteids, mineral salts, and water, without using the carbonaceous foods, but we should die if we tried to live without proteids.

Later on, when we learn more about food, we shall try to find out what are the best kinds for us to eat; but what we specially think of now is that we need a lot of fuel food to warm our bodies and give us energy for our work, and a much smaller amount of building food, for we do not waste away much in the day. Growing children, however, need more, in proportion to their size, for they have to put on many inches in height and in breadth, and those inches have to be made out of the food they eat. It is a great pity to spoil our appetites for the food that makes us grow, by eating sweets just before our dinner; for though wholesome sweets are good for us in their proper place and

in moderation, they cannot add bone and muscle to our bodies, though they can add fat. Meat, fish, eggs, milk, whole-meal bread, dried peas and beans, are very full of body-forming food. Vegetables contain little proteid, but large quantities of starches and sugars, and possess valuable mineral salts. They contain far more water than meat. Of all these foods, however, not one is in a state that can be taken up by the ordinary citizens of the body; all have first to be prepared by special cells and digested by them, and passed on to all the other citizen cells.

Let us imagine a man sitting down to his dinner, and that he has before him a plate of beef and potatoes, and a rice pudding, and some sugar. In the beef he has a large proportion of proteid for the repair of his body. The solids of the potatoes are mostly starch and mineral salts. In the meat is some fat also; and the rice pudding is largely starch, but if made with milk it gives also some body-building power. He adds sugar to it, and so gets the other carbohydrate. All the foods have water in them, so the man has taken in his simple meal all the proximate principles of the body, and in very fair proportion.

The first thing the man does with his food is to cut or break it into small parts, and put it into his mouth. What happens next? He bites it well to make it soft. What does he bite with? His teeth. So the cells which form the teeth are the first cells to begin to prepare the food.

Is the mouth quite dry? No, it has water in it. That water comes from little glands: there is one on each side of the head close to the ear, and a little passage leads from each and opens inside the mouth in the middle of each cheek (parotid glands). You can feel the little openings with the tip of your tongue. Other openings exist under the tongue in front (sub-maxillary and sub-lingual glands), and water can be seen welling up from them. These glands are in shape very like a number of little grapes all clustered together, and are made of cells whose work it is to manufacture water from the blood. This water is called saliva, and it is the first digestive juice. It is not merely water, but contains a ferment (ptyalin), which has the power of acting upon starch. Now before food can get into the blood it must be made *soluble*; that is to say, it must be made able to *dissolve*, as sugar can in water, because it is only in that way that it is able to pass through animal membrane. Will starch dissolve in water? Let us stir a little into this glass of warm water and see. Does it disappear? No. Well, let us at least see if any is dissolved enough to pass through animal membrane. Here is a little piece of bladder. I have put some starch in it and tied it up tightly, leaving a loop to hang it up by, so that it can dip into

this glass of warm water, as you see. Here is another piece of bladder, but into this one I have put sugar, and I will let it dip into this other glass of pure, clean, warm water. After a minute or two I will taste the water in the glass which holds the sugar shut up inside the piece of membrane. It is quite sweet. I open the little bag; the sugar has disappeared. Evidently it has passed through the walls of the membranous bag and got into the water. So we have learnt that sugar can pass through an animal membrane. Salt will do the same. Let us see if starch will. How can we find that out? By tasting the water in the glass? No, that will not help us, for starch has no taste. We must test the water with iodine, and if there is any starch present the mixture will turn blue. What happens? Nothing at all. I will open the bag. The starch is still here; evidently starch cannot pass through as salt and sugar are able to do.[1]

But the cells which digest food are able to overcome this difficulty. They manufacture juices from the blood which can change starch into sugar; let us make an experiment. In this test-tube is some crumb of bread which is surrounded by a little water from the mouth and has been kept gently warm. I will test it by pouring in a little potash solution and then a little less of copper sulphate solution, and afterwards boil it. What happens? It turns brick red. What is that a sign of? The presence of grape-sugar. This special form of grape-sugar is called maltose. There may have been a very little grape-sugar in the bread before the saliva acted on it, for the great heat of baking turns a little of the starch near the surface into a form of it, but what you see here is really the result of the action of the saliva. The sugar which results is not a very sweet sugar like cane-sugar, but it is sugar all the same.

Food, therefore, is broken up in the mouth by the work of the teeth grinding it; it is softened and moistened by the water of the mouth, or, in other words, by the *saliva* present, and in that saliva is a ferment which has begun to turn some of the starch to sugar. The tongue helps to roll the food about and to get it well chewed by the teeth, and then it is passed to the back of the throat (pharynx), and the muscles there close on it, it is then pushed down by the muscles in the walls of the gullet until it reaches the stomach.

There are two tubes in the throat, one leading to the lungs, and one behind it leading to the stomach (fig. 73). The one in front (larynx) has a sort of lid to it (epiglottis), and when we swallow food this lid is pressed on and closes, so that no food can get down the wrong tube and go to the lungs and choke us. Sometimes when we speak with our

[1] The process whereby matters in solution can pass through an animal membrane is called *osmosis*.

mouth full, which is bad manners, or when we swallow hastily, a little crumb or a drop or two of what we are drinking gets into the windpipe (trachea) or front tube, and then it irritates us so much that we cough violently to get it up again.

Here is a picture of the food tube as it passes through the human body (fig. 74). It is just a long passage, shut off here and there by doors, and

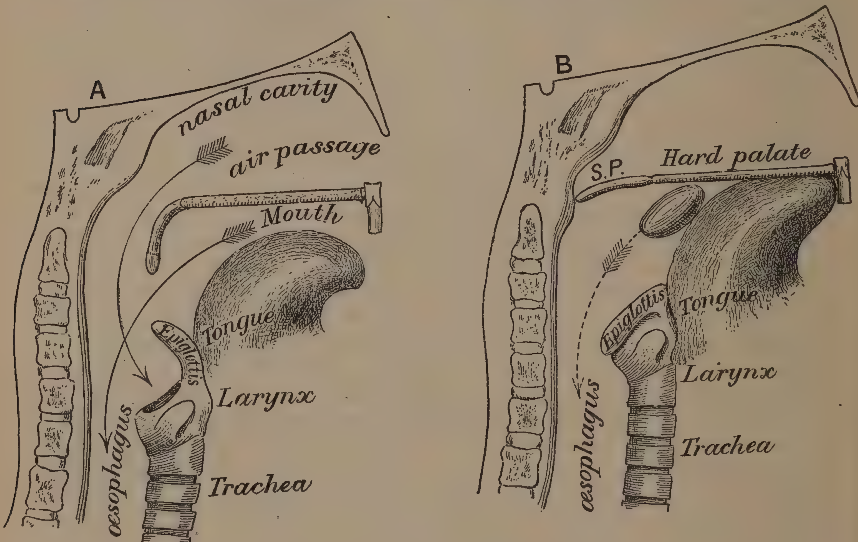


Fig. 73.—Scheme of Deglutition.

A, passages and openings marked with arrows indicating air and food channels. The soft palate is hanging down and the windpipe (trachea) is open. B, showing a morsel of food in the act of being swallowed. Note position of tongue against the hard palate and the epiglottis bent down and protecting the entrance to the windpipe (trachea). S.P., soft palate touching back of throat.

turning round corners, and sometimes opening out into a wide part, but all the same it is just one long tube from start to finish. The mouth and gullet (œsophagus) are the first parts. The gullet is about nine inches long, and here, as you see, it widens out into the stomach, a wide bag with two openings. The different layers or *coats* composing the walls of the stomach are full of very busy cells in glands, which manufacture a strong acid juice called *gastric juice*. The muscles in the walls of the stomach run in such a way that when they contract, which they do as soon as they feel food touching the walls, they move the walls round like a churn, and so the food inside gets well churned up

and is mixed with the gastric juice which the active glands begin to pour out even before the food reaches the stomach. The starchy food in the meal we have been talking of—that is to say, the bread, potatoes, and rice—becomes well mixed and softened, but none of the starch is digested here. The fat of the meat becomes melted and broken up, but though the delicate envelope which surrounds each little drop of the now finely divided fat is digested, because that envelope is made of proteid, yet the fat itself is digested elsewhere. The gastric juice is for the digestion of proteids, therefore the gluten of the bread and the proteids in the meat are first softened and then dissolved, and some of it can now pass through the walls of the stomach and get into the little blood-vessels in them, and so begin its journey to the waiting and hungry cells all over the body.

Fig. 74.—Alimentary Canal.

The food in the stomach is now all softened and churned up, the fat is melted, and the proteids are partly digested, all is soft and creamy, and in this condition is called *chyme*. It now begins to pass out through the lower opening and goes into the small bowel, or *intestine*, as it is otherwise called. The small intestine is many feet long and is coiled up in the belly or *abdomen*, and bound together and held in place by connective tissue. In those animals which eat only meat this part of the food tube is not nearly so long as it is in those that eat only vegetable food. The food tube in an animal like the cow, which lives on grass and hay, has to be very long indeed, many times the length of its body; while in others, like the lion or the tiger, it is only about three times as long, and in man, who is both a meat and vegetable eater, it is about five or six times the length.

The food has now entered the first part of the small intestine (duodenum), and nearly all the rest of the digestion is done there. It here meets with a third digestive juice, which is called the pancreatic

juice, because it is manufactured by the pancreas, an organ on our left side, close under the stomach. The pancreas is a gland, and its duty is to make a juice which will digest all the rest of the food. In it are three chemicals: one acts on proteids and turns them into the form called *peptones*, which can get through the wall of the tube; another acts very powerfully on starch and turns all the rest of it into sugar; and the third acts on fats, and is helped by the bile, which is a juice prepared by the cells of the liver,—this big organ on our right side, to the left of the diagram. A passage from the liver opens into the intestine just where the one from the pancreas comes in, and the bile pours in by it. If there is no food to be digested, and when therefore bile is not wanted, there is an arrangement whereby it is prevented from passing into the food-tube and becomes stored in the liver in a little bladder called the *gall-bladder*. In fig. 74 the liver is drawn up to show the gall-bladder underneath (see also fig. 27). Gall in the gall-bladder is what is called bile after it has passed into the food-tube.

FIG. 75.—Longitudinal section of bowel, showing how the inner lining is thrown into folds which increase the absorbing surface.

The walls of the intestine manufacture another juice which helps in digestion. All this time the food is being moved slowly on, for the walls of the intestine have muscle fibres in them, arranged in such a way that when, after feeling the pressure caused by the presence of food, they contract in response to that stimulus, the effect is to push the food further on. By now it is all digested and is in a smooth liquid state called *chyle*. It begins to soak through the walls and get into the blood. The walls of the small bowel are peculiar, for the inner lining, which is very full of blood-vessels, is much larger than the outer coats, and therefore it has to be wrinkled into folds in order to fit in (fig. 75). These folds are very helpful (valvulæ conniventes), because they increase the surface of the inside of the bowel, and it is through this surface membrane that digested food is able to pass. If this inner lining were put in smoothly, then the tube would have to be made much longer in order to get all the food absorbed. Nature has managed to pack things so as to take up as little room as possible. We remember how wonderfully she has packed and folded the surface of the brain so as to get into the skull as much as she can of the marvellous grey matter made up of the most important brain cells.

These folds in the lining are made still more able to help by the whole surface being covered with little projecting parts rather like the pile of a piece of velvet. Each one of these little projecting parts is called a *villus*, and several together are called *villi*. These tiny finger-like projections dip into the liquid food as it is pushed on by the movements of the muscular walls, and the food soaks through the surface cells and gets into the tiny blood-vessels in the centre of each villus (see fig. 76). These blood-vessels become gradually larger as they pass out through the walls of the bowel, and finally they all join the portal vein, which goes straight to the liver, bringing blood filled with digested food taken up from the walls of the stomach and the bowels. This food consists of digested *carbohydrate* in the form of a kind of *sugar*, also digested *proteid* in a form called *peptones*, and also again digested *fat*. But the fat does not go at once into the blood-vessels. It is not yet sufficiently prepared. It passes instead into a much larger vessel in the centre of the villus, called a *lacteal*, from a Latin word meaning *milky*, because after a meal in which there has been fat these vessels are full of milky-looking digested fat which they have taken up. These lacteals are lymphatic vessels. They enter into and branch through the great membrane called the *mesentery*, a word which means "in the midst of the bowels." It is a part of the lining membrane of the belly or abdomen (peritoneum), and covers in the coils of the food-tube and helps to bind them together and keep them fixed to the walls of the body.

Fig. 76.—Transverse section of bowel, showing the projections of the lining surface (villi) dipping like fingers into the inside of the tube. Through these villi the digested food passes into the blood. Blood-vessels are shown branching through the walls.

In the mesentery the lacteals, now called lymphatics, widen out into glands, and in the glands the fat is altered and made fit to go into the blood. It passes on into a large tube called the *thoracic duct*, which runs right up to the root of the neck and pours the fat into a large vein there (superior vena cava). In this way the proteids, carbohydrates, and fats of the meal of beef, potatoes, and rice pudding all reach the blood.

So we see that the business of the upper part (duodenum) of the small intestine is to hold the food while it is being mixed with the pancreatic juices and with the bile from the liver, and all that was not digested in the mouth and stomach is digested in it. The work of the rest of the tube (jejunum and ileum) is to squeeze the food slowly on while its walls absorb it. If the food passed on too quickly, then the

nourishment in it would not have time to soak properly through the walls. The great business of the larger part of the small intestine is therefore *absorption.* By the time it comes to the end of the small intestine almost all the nourishment has been taken out of the food. The intestine now opens on the right side of the body into the large intestine, which, as you will see from the diagram (fig. 74), passes upwards and crosses the body under the stomach, and then passes downwards on the left side and ends in the rectum, a passage opening out of the body. During all this time the food has water taken out of it by the walls of the large intestine, and it becomes nothing but rubbish. It is this useless part, which cannot be any further digested, that should be got rid of regularly. If it is allowed to remain in the large intestine, germs which are always present in this part, grow in it and may possibly cause unwholesome matters to be formed. These matters may, in their turn, pass through into the blood. Where is that blood going first? To the liver. Yes, it enters the portal vein, which comes filled with food material. But if people neglect *inside* cleanliness, that blood from the walls of the large intestine is also bringing a little poisonous matter. The liver does its best to make the blood quite pure before it sends it on. Its business is very important. It is made up of masses and masses of busy cells whose duty is to store up certain food and give it out as required, and also it has to try to stop any harmful things from getting into the rich blood it sends out to the heart. Foolish people who drink much strong drink in the form of beer, wine, or spirits cause alcohol to get into the blood and be carried to the liver. Now alcohol is very bad for the liver cells, and sometimes hardens them so much that they cannot do their work properly, and therefore the whole body suffers.

We see from this that the liver is a sort of storehouse in which the body keeps digested food. A little food is always passing away from the liver with the blood and is being sent to all the parts of the body.[1] The blood as it leaves the liver goes first to the right side of the heart. Why? In order to be sent to the lungs to get rid of the carbon dioxide it has collected. It comes, therefore, as dark purple blood but full of food matters. The heart sends it through the lungs, where it gets rid of the harmful gas and takes up oxygen. Then from the left side the heart sends it out to carry food and fresh air to every part. Now stop for a moment and think what we make the heart do if we neglect good habits. The blood comes to the liver with poisonous matter in it from the rubbish in the food tube. Perhaps the liver cannot prevent it all from passing on, or even is so injured by it that it cannot do its work properly. The blood now leaves the liver and goes to the heart

[1] Carbohydrate is stored in the liver in the form of animal starch or *glycogen.* It is given out slowly, as required, in the form of a sugar.

bringing the poison with it, and the heart passes it on through the lungs to its left side. What happens next? The heart does its duty by sending out what the cells of the food-tube and the lungs have worked so hard for, namely, blood full of food and fresh air, but in this case, owing to neglect, *a little poison also.* Where does the blood go to first? A little artery goes to nourish the walls of the heart itself. What does it bring? Food, and fresh air, *and a little poison.* This blood goes everywhere. All over the body the eager cells are waiting for food. And the arteries come to every part splitting up and getting so thin and fine that the nourishing lymph can soak through the walls and be taken up by the cells, which also take out the oxygen and combine it with the carbon brought as sugar, the result of the digestion of that rice pudding and those potatoes. They take out the building material too and use what they want, and then, as we have learnt, the waste matters return to the blood to be carried by veins to the right side of the heart. Some blood goes a very long way round through the kidneys to get rid of the waste of proteid matter, some goes round by the walls of the food-tube and the liver, some only the short journey through the walls of the heart itself; but wherever it goes it brings food and fresh air. However, in a case of self-neglect, when the lower bowel is full of poisonous matters, the blood carries this poison also everywhere it goes. The blood goes to the brain, and instead of bringing only food and fresh air it brings *a little poison* as well. It goes to the nerves and leaves *a little poison* with them. It goes to the walls of the blood-vessels themselves and gives them food and fresh air *and a little poison.* It goes to every organ in the body. What wonder, then, if people who neglect to get rid regularly of waste matter feel often rather ill? *They are poisoned by themselves.* Their heads ache, they feel dull and heavy and sleepy. They often feel very tired, though perhaps they have done nothing to tire them; they are slack and good for nothing; they are often cross and irritable, and often gloomy and sad. They think something bad must be going to happen to them because they feel so miserable, and often if people look for trouble they make it come. If the neglect goes on, the health of the person may suffer severely. A poor condition of the blood known as anæmia is often caused or made very much worse by constipation, and anæmia in its turn means that the body cannot be properly supplied with fresh air, for in poor blood there are not enough of the little red cells which carry oxygen. As a result of this the walls of the intestines find it very difficult to do their work properly, and so matters get worse and worse. It is a disgusting idea to keep waste matter in the body to poison it. It must be got rid of regularly. It is very good for health to eat whole-meal bread and plenty of vegetables and ripe fruit.

Young people do not need to be told to take plenty of exercise; boys and girls are always running and jumping about when they are not in school, and running and jumping help to make good digestive juice. How can it possibly do that? Exercise of the muscles of any part of the body sets the blood flowing more rapidly to the lungs, where it gets well filled with fresh air. This well-purified blood is pumped vigorously by the heart to the walls of the stomach and intestines, whose cells therefore get more nourishment brought to them and are able to make more digestive juice. So you see it is true what is said by scientific people, that the calves of our legs help to make digestive juice.

Exercise also helps the liver to do its work, and therefore the whole digestion benefits, and through the digestion the whole body. It is very bad for the digestion of body-building foods to eat a quantity of sweets just before dinner, partly because they spoil our appetite, but also because the presence of much sugar in the stomach prevents the easy digestion of this important kind of food. Another thing to remember is that after eating it is not good to *stoop* over work or a book. Stooping is never good, but it is particularly bad after eating, as it prevents the proper movements of the digestive organs. Drinking strong over-drawn tea with a meat meal makes it very hard for the stomach to digest the latter. Bad teeth, which cause food to be swallowed without being properly broken up, is a frequent cause of indigestion. It is very hard for the stomach to digest the food if the teeth have not done their proper share of the work. Every care should be taken of the teeth from the earliest childhood, for they are of the greatest importance to good digestion.

Blackboard Summary.

1. Food is needed to give us heat and energy, and to build up and repair the body.
2. Body-warming foods are proteids, starches, sugars, oils and fats.
3. Body-forming foods are proteids, mineral salts, and water.
4. Food needs to be well chewed.
5. The food-tube passes right through the body, and in it the food is broken up, digested, and absorbed into the blood.
6. The food-tube is divided into mouth, gullet, stomach, small intestine, and large intestine.
7. Digestion is begun in the mouth, carried on in the stomach, and finished in the intestines. It is done by the aid of certain juices, principally saliva, gastric juice, pancreatic juice, and bile.
8. Absorption of the digested food takes place mainly in the small intestine.
9. Food rubbish, if kept in the body, does it great harm.

CHAPTER XXIII.

FOOD LARDERS AND DUST.

Necessary Apparatus.

Good examples of mould on fruit, bread, etc.
Preparation of potatoes and glasses, etc. ; see lesson on *Hair and Nails*.
Slice of dry bread under glass / Slice of damp bread under glass } prepared four days beforehand.
Test-tube containing dry hay / Test-tube containing soaked hay } prepared four days beforehand.
Hand-lens.

Accessory Apparatus.

Good compound microscope, $\frac{1}{6}$ or $\frac{1}{8}$ inch objective. Specimens of tinned foods in good tins, contrasted with specimens in "blown" tins.

We are very much in the habit, when we hear of "germs," of thinking of them as things which only concern doctors and scientists. But they concern every mistress of a household, and every cook, as well as many other people who have to think about the care of a house and about food and its preparation. We have already learnt how tiny these unseen friends and foes are, and that it would take many thousands of them, put end to end, to form an inch, so that they can only be seen under the microscope, except when they form colonies. These little organisms are therefore often called by a very long name, *micro-organism*, signifying how small they are. A simpler name for them is microbe, which in some ways is better than "germ," as germ is also used for much bigger things, such as that part of the wheat-grain or other grains or seeds from which the new plant will spring (see fig. 79). There are three kinds of microbes which have to do with our houses, and they are called *yeasts*, *moulds*, and *bacteria*.

Sometimes we hear people say that they are terribly troubled by rats and mice in their homes, and that the mice get into the larder and eat the food ; and we hear about insects also. But it is not everyone who understands that, unseen by our eyes, there is a great host of minute enemies trying to feed upon our food. All the microbes we are about to study to-day are alike in one thing, and that is that they are what botanists call "colourless plants." They have colours, certainly, for

we find blue mould, and green mould, and yellow mould, and red mould, and also bacteria which form colours, but they do not possess the true green colouring which most plants have (chlorophyll). Plants which have not got this particular green colouring are unable to live on the very simple food of other plants, but use the same kinds of food as animals. Therefore animals and germs are always taking food from each other.

Moulds are much larger than yeasts or bacteria, and are very common everywhere. They can usually be seen by the naked eye, and form long threads which, in still air, will grow out like masses of fluff. Otherwise they mat themselves together or send their long threads down into the things upon which they grow. When an almost invisible mould begins to grow it soon becomes very easily seen and sometimes grows enormous. One little speck of mould on a fruit will soon make it a mass of decaying matter. Soft, juicy fruits whose skins are thin and full of roughnesses "go bad" soon, because moulds can find resting places on the roughnesses of the skin and pierce through quickly. Peaches form a good example of fruit of this kind. Fruits with thicker skins will keep much longer if the skins are wiped often with a clean dry cloth, and the wrapping of fruits in paper is a simple and very good way of helping them to resist the attacks of moulds, for the paper prevents damp from settling on the skins, and moulds cannot grow without it.

There are many different kinds of moulds. Here is an apple with a big mould growing on it. We will cut it in half through the mouldy part, and notice how the growth has got right inside and is destroying the good pulp. If we put a thin slice of such an apple under the microscope, we can see the threads of mould running through it. Look at the growth outside and notice the threads; these threads form little seeds or spores on the ends, and the least breath of wind will carry them far and wide. Sometimes if we touch one of these colonies of mould we disturb so many of the tiny seeds that they get into our nostrils and make us sneeze. Mildew is another name for mould. We have just heard that all moulds need a certain amount of damp before they can grow. Here is a small slice of bread on a clean saucer and covered over with a glass, which latter I took care to wash very carefully. The slice of bread was dried a little before I put it under the glass, four days ago. The bread looks quite clean and wholesome still, although of course rather dry. Here are two or three more saucers and corresponding bits of bread all under glass, but all three were damp when I put them in, and one or two of them look and smell mouldy and nasty. Here also are two test-tubes prepared three or four days ago. In both is a little good hay. Smell this one. What is the smell like? Fresh and sweet like good hay. Here is the second, what is its smell like? Very mouldy and nasty. That is because I soaked the hay in water

before I put it in. Hay is full of germs of different kinds, as we should realise if we took a little drop of water from the second test-tube and put it under the high power of the microscope, for we should see the water swarming with life. These experiments help us to understand why food should be kept in a dry place.

Bacteria are very important to the housewife, as well as moulds. They are very small and need a very high power of the microscope to enable them to be seen at all. They usually multiply by becoming a little larger and then dividing into two. Some, however, form spores which are very difficult to kill. Most germs grow best in darkness, dampness, and warmth. Moulds grow very quickly in a damp, close, stuffy room. All germs grow more quickly in damp, hot weather. That is why on thundery days milk and other things keep so badly. It is not the thunderstorm that turns the milk sour; it is that the damp heat which causes thunder suits the germs. In some climates it is so damp that everything becomes covered with moulds, and in others it is so dry that they never grow at all.

Germs are present in most places: they are in the air we breathe, in the water we drink, on the food we eat, on our skin, our clothes, our furniture; and where most people are gathered together, there are likely to be the most germs. They are not found, however, in air far away from the haunts of men and animals and where they cannot get food. For instance, the air collected on the tops of very high mountains and in the middle of great oceans is found to be free from them. They are not found in the muscles, and organs, and blood of healthy people, though they are always present in the food-tube. They are not found in deep spring-water or in the deep layers of the soil, but they are nearly everywhere else. Great heat such as boiling will kill them, but some need a higher temperature still. Great cold checks them and prevents them from growing, but ice, if made from dirty water, can be full of dangerous germs. It takes weeks of freezing to kill germs in ice.

Moulds growing in food make it look nasty and give it an unpleasant taste. Although it may not be dangerous, yet it is unwise to eat mouldy food, and all mouldy parts should be carefully removed, and a part also of what looks good around it, for that part is probably full of the invisible threads beginning their work of destruction. Many cheeses owe their peculiar flavours to the moulds which are allowed to grow in them, and which have been found by experience to do no harm and to give flavours which people like. The moulds and bacteria which are found in some places give distinctive flavours that cannot well be obtained elsewhere.

All decay and putrefaction are the work of germs of one sort or another, and those which attack food may form poisons as they grow.

It is possible to eat food which contains bad germs and to have an illness after some time owing to those germs having obtained entrance into our bodies and having attacked us. For that reason we are very particular not to allow meat to be eaten if it comes from an animal which was suffering from any illness caused by germs; nor do we allow milk to be sold which has come from cows suffering from such an illness as tuberculosis, very often called "consumption." Germs which may succeed in getting in to our bodies and do not get killed quickly, may, if they grow, form poisons and gradually make us ill. But it sometimes happens that the germs have already formed poisons in the food itself, therefore if we swallow these poisons we may be very ill in an hour or two or even less. These are the reasons why we need to be very careful to keep food clean and cool, and also why we must never eat tainted food, or food prepared in dirty places. We pay certain of our fellow-citizens to look after these matters for us, and they inspect the dairies and milkshops, and the places where animals are killed and kept, also shops of various kinds, and bakeries, and markets, so that we may be sure of getting pure, good food. But it is not only necessary to pay others to take care: we must take care ourselves, and see that, if food comes fresh and wholesome to our houses, it is properly looked after there also.

Bacteria growing in food taint it. Thorough cooking usually kills any germs that may be in the food, but it does not destroy any poison that may possibly have been developed in food that is not quite fresh. These poisons that may be developed in animal food are known as *ptomaïnes*. They are poisons specially formed in dead bodies, which is what the Greek word means from which their name is derived. We have learnt before that germs are always pulling dead things to pieces, whether it is a sparrow that falls to the ground or a leaf fluttering down from a tree. As the germs grow, they set free the simpler compounds such as ammonia (containing nitrogen) and carbon dioxide gas, and water. Life will use these up again, for we saw before that Nature never wastes anything, but uses it over and over again, so that what to-day is part of a rose may some day be part of a human being, or the dead sparrow may in its turn give part of itself to form the flowers of the field. All living things are related to one another.

Life itself prevents germs from growing; they can only grow when life has gone, except the few parasitical ones which cause illnesses, and even these we are learning to conquer. But the dead leaf or the dead bird cannot resist the germs, and if we want to keep them a little longer we must keep germs away as well as we can. We can keep meat for months if we kill all the germs in it by means of great heat. Meat can be preserved in good condition for years if placed in tins and cooked at a very high temperature which kills the germs. After the

meat has been placed in the tin the latter is closed, all except a small hole; it is then heated, air and steam escape by the hole, which is quickly sealed up, and a tin of good meat can be known by the fact that its ends are slightly pushed inwards by the outer air pressing on them, and being stronger than the inside pressure as soon as the tin has cooled down. If, however, the germs have not been all killed, they can begin to grow from the few that are left, and by and by they will form gases, as a result of the decay they are causing in the meat. These gases fill the tin, and in time will make the ends bulge outwards. Such tins are known as "blown tins," and the food they contain is dangerous. Tinned foods should be turned out of the tin at once after being opened; they should be stored in a cool place, and not kept long before being eaten.

Sour milk is milk in which souring germs have grown (lactic acid organisms). It is wholesome enough as a rule, except for young children. The acid usually prevents more dangerous germs from growing. But milk that is *tainted* is always dangerous and should never be drunk.

Many things can be done to help food to keep. Sugar is a great preservative, as the housewife knows who puts it into her jams and jellies, and she is well aware that they will easily go mouldy if she uses too little. Salt, spirits, and various chemicals are in use to check and destroy germ life.

The best practical way for a household is to remember what germs like and what they do *not* like, and to give them as much of the latter as is possible. For that reason, the larders and cupboards where food is stored ought to be places where no germ cares to live. I am afraid that is not always so. In many small houses there is no proper place for food, and it has to be kept in a dark, stuffy cupboard. Evil germs love *stuffy, stagnant air*, therefore we want our larder to have fresh air blowing through it. If we cannot have two windows, we can perhaps have one window and a ventilating brick. Evil germs love *darkness* and a certain amount of *warmth*, so we would like our larder to be on the north side, if possible, that we may have plenty of light, but no direct sunlight to make the place hot. Germs love *damp*. Our larders must therefore be dry. They ought not to have much wood, which needs scrubbing and holds the damp afterwards. A really good larder ought to have a stone, or tiled, or cemented floor, and the walls ought to be of tiled or glazed brick, or some easily washable material. Shelves should be made of slate, or stone, or glass, or be covered with some special material which will not hold damp and can easily be washed. Shelves like these can be wiped down with a cloth damped with salt and water, and can be made sweet and clean with very little trouble.

In any case, whether we have wooden floors and shelves or not, our larders should be kept very clean and not be built near anything which smells or is dirty, such as drainage arrangements or dust-heaps; for another thing which germs love is *dirt*. Windows should be open and covered with wire gauze to prevent dust and flies from entering and bringing germs with them. *Cool*, *fresh*, *sweet*, and *clean*: such must always be the words we can apply to the places where we keep our food, and the jugs and basins into which we put it. Always cover food away from dust and flies, and remember that germs love *darkness*, *dampness*, *dirt*, *stuffiness*, *and warmth*, and that they very much dislike *brightness*, *dryness*, *cleanliness*, *fresh air*, *and coolness*.

Let us collect some dust and see if we can find out if it holds many germs. I have here all the arrangements for getting slices of boiled potato safely under cover of glasses without germs, as we had when we tried to see if any germs lived in the dirt under careless people's nails. Now we will prepare some more pieces of potato in the same way, and when we have got them all ready we will pass a knife through the flame of the lamp so that we burn up any germs which might be on it; and then with the knife we will collect any dust we can find on the floor and between the boards, on the tops of the cupboards, and in out-of-the-way corners. I hope we shall find it quite difficult to collect dust from this room. Then we will lift up the glasses just a little way and scatter the dust over the surface of the slice of potato. Every person who does this will place a label on his or her glass and put it away until next week. Where shall we put them? In a cool, bright place? Oh no, in a warm, dark place such as germs love, where no one will disturb them.

. . . .

Now that nearly a week has passed since we placed the dust on the slices of potato and put them carefully away, everyone must bring his or her own out from the cupboard, but take care not to move the glass. We will put them all in a row and look at them. Here is one on which we did not put any dust. What does the potato look like? It looks much the same, except that it has shrunk a little and looks rather hard and dry. Let us look at this one. Here is a curious sight. The whole glass inside is filled with feathery white threads. If we look closely we can see little tiny seeds at the end of the threads. These are spores. The least movement of air will scatter them about, and there were evidently some of them in the dust you sprinkled on the potato. Now we will take the cover off and look more closely. Do you notice any smell? Yes, a nasty, musty one. What is the potato like? It is all overgrown, and yet we can see that it is nasty and soft, and changed in colour. Here is another specimen. The potato is

covered with little groups of moulds, or colonies of them, as we call these groups. Here and there are different-looking colonies, not fluffy like the others; they are bacteria. They look like little bright dots of yellow or red and different shades of colour. There is one bacterium of the kind called from its shape a bacillus, or "little stick," as the name means, which is sometimes found growing in damp bread or paste. It grows in colonies so bright red in colour that they look like little drops of blood, and ignorant people have been much frightened by them in days past. We are not likely to have any here.

One of our potatoes looks quite horrid. It has turned a shiny yellow and has a very bad smell. That is done by a bacterium which is one of many kinds able to turn things liquid and putrefy them badly.

How many things we can learn from these experiments! We had no idea that lurking in the grey dust were these active germs ready to spring on and destroy our food. We can experiment easily with pieces of bread just damped a little, and covered up by a glass tumbler, and sprinkled with dust. We can also put pieces of many things away rather damp and study the colonies of germs which grow on them. Certainly we shall be careful to keep our food away from flies and dirt and damp, when we realise what germs and dirt can do. Sometimes we find that a cupboard or a larder has begun to keep things badly when it used to keep them well. That may mean that some particularly tiresome germs have got in, and then we shall be obliged to have a very special cleaning out of the place, and perhaps use disinfectants, before we can get rid of them.

Now let us sum up some of the things we have learnt :—

Blackboard Summary.

1. There are three big divisions of germs: yeasts, moulds, and bacteria.

2. Moulds and bacteria are enemies to the housewife; they destroy food and make it unwholesome.

3. Cooking may destroy germs in food, but it will not destroy any poisons that may have been already formed by the action of the germs.

4. Tinned foods should be turned out when the tins are opened, and used as soon as possible, for they never "keep" well.

5. Germs love dirt, darkness, dampness, stuffiness, and warmth. They hate cleanliness, brightness, fresh air, dryness, and coolness. Therefore our larders should be clean, dry, cool, and airy.

6. Germs hide in dust, therefore get rid of dust and you will get rid of many germs.

CHAPTER XXIV.

MILK.

Necessary Apparatus.

A $\frac{1}{4}$-pint of milk.
Distilled water (pure, clean rain-water will do).
A little 2 per cent. acetic acid.
A vessel in which to shake up the milk ; a large test-tube will do.
A large funnel.
Filter paper.
Water.
Glass rod.
Vessel to receive filtrate : a glass jam-jar will do.
Test-tubes.
10 per cent. potash solution.
Solution of copper sulphate, 1 per cent.
Spirit-lamp or Bunsen burner.
Matches.
Dilute iodine solution.
Millon's reagent.
Methylated ether.

Accessory Apparatus.

Microscope.
A tin of preserved whole milk of a good brand.
A tin of skimmed or separated preserved milk in order to point out the description on the label.
A tin of unsweetened whole milk.

We are going to-day to speak about milk, because it is one of our most important foods, and has been called a perfect one. In this country nearly all the milk we drink comes from the cow, but in other countries it is obtained from the goat, the buffalo, the camel, and the mare; also for invalids asses' milk is occasionally used. One of the most important things is that milk should be *clean*. People know much more than they used to do about the dangers of dirt and germs, and they realise that many illnesses can be carried by dirty milk. The byres where the cows are kept must be clean and airy, and the cow herself kept clean.

Then the milker must have clean hands, and wear a clean overall, and the pails must be well scalded and be kept exceedingly sweet and

clean. A dirty cow, from whom dirt and hairs drop into the milk pail, is giving untold numbers of germs to the milk, which will help to make it go bad very soon, for milk comes warm from the cow and is a rich food for germs, which, aided by the warmth, grow at an enormous rate. It is a beautiful thing to see the exquisite cleanliness of a big, modern dairy farm in which every care is taken that no dust and no dirt can get into the milk, and when dust and dirt are kept out very few germs can get in.

It is sad to think of the number of tiny babies who become ill from drinking dirty milk, in every few drops of which there may be tens of thousands and even hundreds of thousands of germs. It is always better to boil the milk for babies and very young children and so kill the invisible enemies which do so much mischief. Boiling practically destroys all harmful germs, but does not get rid of all those present. Sterilised milk is milk which has been kept for at least two hours at a temperature above boiling-point. It is sold in sterilised bottles, and costs a little more than ordinary milk because of the cost of preparing it. It contains no germs at all. There are other ways of preparing milk, such as heating it at 176° F. This kills the germs which turn milk sour, and it also destroys or weakens a good many harmful ones, and yet does not give the strong, cooked flavour of boiled milk. The method was invented by the great French scientist Pasteur, and milk treated like this is called pasteurised milk. Although milk can be pasteurised at home by putting bottles of milk, stoppered with cotton wool, into boiling water for twenty minutes or half an hour, or by using a special vessel which can be bought, it is really better for the ordinary household to boil the milk it uses.

Sometimes the dairy people and the shops are very clean and careful, and the people in the houses very careless. They do not take care to see that the jugs or cans are perfectly sweet and fresh. They are not careful to see that the milk is put into the coolest possible place and covered over from flies, which always carry dirty germs about on them.

Now we will see if we can find out something about milk for ourselves. If we look at a drop under the microscope we shall understand more easily. We have put on the slide only a *very* thin film of milk. What does it look like? When we look through the microscope we will each try and draw what we see. It looks like a quantity of round little grains floating in water. Those little grains are tiny globes or *globules* of fat, and such finely divided fat is called an *emulsion*. This fat, when it rises to the top, is called *cream*. There are other things in milk which we cannot see, because they are in solution. Let us see if we can find out any of them.

Here is a little fresh milk. I will add to it three or four times its

own quantity of distilled water, and then a little acetic acid of the strength of 2 per cent. Then I will shake it all well up, and gradually the curd, or solid part, will separate from the watery part or *whey.* Here is a clean glass funnel which I will line with this filter paper, taking care to soak the paper with water first. Now I will pour the diluted milk, which is beginning to curdle, into the funnel, taking care it does not come above the filter paper, and as the milk is heavy and might break or tear the wet paper as it goes in, I will hold a glass rod in the funnel and let the milk run down it as I pour, so that it reaches the paper very gently. I have put the tube of the funnel into this glass jar, so that we can watch the filtrate as it drops slowly through. I have used a big funnel as time is precious to us and milk filters very slowly. What do you notice? A pale, straw-coloured liquid comes dropping out. That is what we call "whey." What is in the filter paper now? A thick white substance. That is what we call "curd" We will keep the curd carefully. We have now got enough whey, for we need very little for our experiment. We will put a few drops of it into each of five separate test-tubes. What are we going to test milk for? We are going to see if it contains all the proximate principles of food. Shall we test first for carbo-hydrates? What are the carbo-hydrate foods? Sugar and starch. Yes, so we will first test for sugar, using our former means for finding sugar in grape-juice.[1] Here is a little of the filtered milk, and I will put into this test-tube some 10 per cent. potash solution, taking care to put in rather more potash than I shall put in of the copper. Now I will add a few drops of copper sulphate and shake it all up together. What happens? The mixture turns a dark blue. Now I will warm it in the flame. Do you remember what will happen if sugar is present? Yes, the liquid will seem full of fine red sand. Is anything happening? Yes, the colour is turning, and now it is bright red. *Sugar is present.* So we have found out that this watery-looking whey holds sugar. This sugar is called *lactose* or "milk sugar"; it is not nearly so sweet as cane-sugar, and that is a good thing, for we should very soon get tired of milk if it had as much cane-sugar in it as it has of lactose, but as it is only so slightly sweet we can take a great deal of it. This sugar is a valuable fuel food for babies and growing children, and is one reason why milk is such a good food for keeping up the strength of delicate people and invalids. Sometimes people buy lactose at the chemist's and add it to milk when they want to make it more nourishing in cases of illness. It is very digestible and nourishing.

Now we will test for the other carbo-hydrate, starch, by adding iodine. Is there any blue discoloration? No, none at all. There is

[1] See Chapter XXI., p. 159.

therefore *no starch at all in milk*. Starch, except glycogen or animal starch, is a vegetable production and requires a special digestive juice. This juice young animals have not got, and Nature takes good care not to give them what they cannot digest. It is ignorant human beings who put starchy foods into babies' milk before the poor little things can digest it. We shall say more about this later on, for it is very important indeed.

We have now found out that milk contains carbo-hydrate in the form of sugar, but *not* in the form of starch.

Now we will see if there is any body-building power in the whey. We will take this third test-tube and add a little from this bottle (Millon's reagent). What happens? A little white cloudiness forms. Now I will boil the mixture. The cloudiness (precipitate) turns brick red. You will remember, when we tested the gluten in flour, that this was a sign of a proteid being present. So we learn that even in the whey there is a body-building power. This proteid is called *milk-albumen*, and is very light and easily digested. It is the part which forms a skin on milk when it is boiled.

Can you tell me of another proximate principle? Yes, water. *Milk contains about* 87 *per cent. of water*; that is, less than a turnip, for that contains 90 per cent. Can you give me another proximate principle? Yes, mineral salts. We will see if the whey contains any. Here is a little whey in this fourth test-tube, and I will add a very little ammonia. What happens? A white cloudiness appears (a white precipitate forms). That is a sign that *phosphates are present*. These phosphates are phosphate of lime and phosphate of magnesium. These are most important salts for building up bone and muscle. To this other test-tube we will add a few drops of silver nitrate and just a drop or two of strong nitric acid. What happens? There is a slight cloudiness (a white precipitate forms). That is a sign that *certain salts called chlorides are present*; one of them is chloride of sodium, which is the common salt that we eat at table.

Now we will turn our attention to the solid part of the milk which we left in the filter paper. Let us see if we can discover any fat present. We will shake up some of the curd with a little ether and then pour it out on to some filter paper. What happens? The ether evaporates and leaves behind it a strong greasy mark. *There is much fat present.* Lastly we will take the rest of the curd and test it for proteid as we did the whey. What happens? The mixture turns deep red. There is *much proteid present*. That proteid is casein, and is what cheese is made from.

We have now learned a great deal about milk. First, we learn that we can separate it into curds and whey. Secondly, we learn that it

contains all the proximate principles—namely, proteids, carbohydrates, fats, mineral salts, and water. Milk not only contains all these, but it contains them in the *right proportions to support life.* No other food does this, though oysters have all the proximate principles, and even have all the kinds, for they contain animal starch. Bread contains all the proximate principles except fat, of which it has a mere trace. But ordinary white bread does not contain these principles in the right proportions. It has too little building material and far too little fat; while milk, on the contrary, has a great deal of both, because it is meant by Nature to be the food of young creatures, who are of course growing and need a relatively large proportion of building material. Young creatures also need fat, which maintains the warmth of their bodies and also helps to build up the nervous system. The mineral salts in milk are excellent for the growth of bones and teeth. Milk has been called a perfect food, but it is really only perfect for the young creature for whom it is intended. It is not perfect for grown-up people, because it has too much proteid for those who have built their bodies, and, though it turns to a soft solid in the stomach, yet it is not really solid enough for grown people for any length of time, and it gives no exercise to the teeth. It makes a very bulky food, for, if nothing else were taken, it would have to be drunk in large quantities by anyone who was leading an active life and requiring plenty of nourishment. It is, however, an excellent thing as an article of food, and especially if people are not very strong, while for children it is invaluable. Dr Hutchison has pointed out that a quart of good milk has the same nourishing value as a pound of beefsteak. A rice pudding made with milk is very nourishing.

When milk is skimmed or separated, the cream is taken off for butter, but all the other things about which we have learnt are left behind; therefore, if people find it difficult to get enough meat and other nourishing things, and are able to get skim milk, they are very wise if they give it freely to their children to drink, for it contains all the body-building power, casein. Of course, new milk is better if it can be obtained; but where every penny has to be counted and people can get skim milk, it is the greatest mistake to despise it just because it has not got the cream in it. Fat can be given in some other form. There was once a big family who were very poor, but they could always get plenty of skim milk very cheaply from a farm near by. The mother of the family used to let them all drink it freely, but she took care also that they had plenty of fat, either in the form of dripping, or margarine, or butter, or suet puddings, for she knew that growing children must have fat in some way. Those children all grew up, there were eight of them, and they were all very tall and strong, and people said that it was due to the sensible way that their mother fed them when they were young. The boys used to eat a good

deal of cheese, which weight for weight has more body-building power than meat, and is made, as we know, from the curd of milk.

Many people nowadays make use of condensed milk when they find it difficult to get fresh milk. It should be remembered that condensed milk does not possess the proper form of citric acid which is found in fresh milk. This citric acid is most important to a child if it is being fed entirely on milk foods. Much condensed milk, also, is skimmed milk. Another thing against condensed milk is that, in order to make it keep after the tin is opened and exposed to the air, much sugar is added to it. The law obliges the manufacturer to put on the tin whether the milk is whole or skimmed, but the public very often does not read what is stated in small print, and very often thinks it is buying something better. Such skimmed and preserved milks when mixed with water, according to the directions, are very poor in body-building power, have hardly any fat at all, and are quite unsuitable for giving to babies. The best brands are made of whole milk; but the sweetened kinds are so very sweet, and such a quantity of water has to be added before they can be drunk, that the milk becomes much weaker than cow's milk. The unsweetened kinds are the best, but do not keep so long when the tin is opened, and must be kept in a cool place. When two parts of water are added, the milk is very like the composition of good, pure cow's milk, but is dearer. Dr Hutchison says "the only kind of condensed milk to be unreservedly recommended is that made from whole cow's milk without the addition of sugar."

Blackboard Summary.

1. Everything in connection with milk must be spotlessly clean.
2. Dirty milk, even if it does not look dirty, contains millions of germs in a few drops.
3. It is always safer to drink boiled milk, and milk for babies should always be boiled.
4. Milk is a very nourishing food, and contains all the proximate principles and in the right proportions to support life. No other food does this.
5. Milk is the food of very young creatures, and therefore is full of body-building power.
6. Milk contains no starch.
7. Milk is very nourishing for children, delicate people, and invalids.
8. Condensed milk is very unlike fresh milk, unless it is one of the unsweetened kinds.

CHAPTER XXV.

FOOD: SOME SPECIAL FOODS CONSIDERED.

Necessary Apparatus.

A Barcelona nut.
A few dried haricot beans, well boiled. A tablespoonful will suffice.
Lamps or Bunsen burners.
Chemicals for food-testing as in previous lessons.

Accessory Apparatus.

Other food materials to test.
Scrape and test scrapings from a raw potato. Be careful to heat the scrapings first in a test-tube in order to burst the starch grain, or there will be no proper reaction.
Raw white of egg for specimen of proteid.
Other foods as desired.
Examine starch grains under the microscope. Scrape from raw potato and smear on slide with drop of water, put on cover-glass and examine.

We have already learnt a good deal about the food we eat, and we know that in order to keep well and strong we need some of all the five different kinds of food. Proteid—that is to say, food with the element nitrogen in it—is the most important of all, for without nitrogen the body could not grow. Nitrogen is like the clay of which the bricks are made for the building of the house of life. We recollect also that we need starchy and sugary kinds of food (carbo-hydrates), and fats and oils (hydrocarbons), and that these kinds contain the important element carbon as their principal ingredient, and that carbon is specially the coal of the body. Besides these we need mineral salts and plenty of water.

Children require less food than adults, but more in proportion to their size, because they are still adding brick after brick to their houses, and they require more fatty and sugary foods, also in proportion to their size, for they lose heat more rapidly and therefore need to put plenty of food-coal on their body fires. Meat contains a high proportion of the valuable proteid, but we already know that other things contain it also. We saw that flour contains the proteid called *gluten*; milk contains *casein*; peas and beans contain *legumen*,—all proteid matters. Animal foods and certain vegetable foods also hold a large quantity of this body-building

power. Meat is one of the most important of all foods, for, as it holds all the body-building materials, we could live on it alone with water to drink; but we should have to eat a very large quantity of it in order to get enough heat and energy for our work, though we need comparatively little for repair of the waste of every day and for growth. The large amount of proteid we should have to eat in order to get enough carbon from meat would throw a great strain on those organs in the body which have to get rid of the waste of nitrogenous food, and the kidneys would probably suffer in the end. Meat is also the most expensive form of

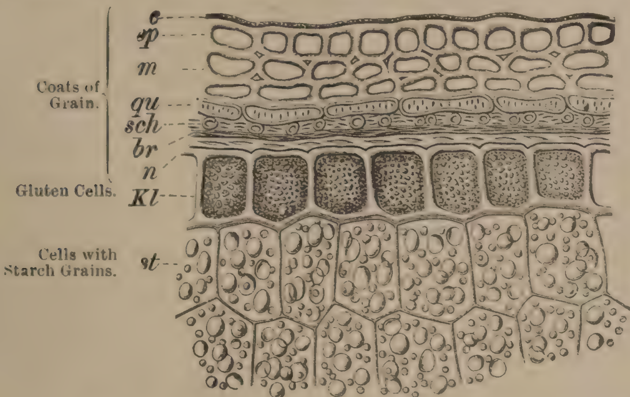


FIG. 77.—Wheat Grain. Part of section. × 200. Showing the position of the gluten cells under the coats of the corn. Notice also the large cells containing starch granules.

proteid. As it is so expensive it is sometimes very difficult for poor people to get as much of it as they would like to have, and they have to think how they can spend their money to the best advantage. People who are obliged to think twice over spending a very little money cannot afford to buy the best cuts of beef and mutton, for they pay extra for those parts; but they can get other parts which will contain quite as much nitrogen. If there is not much meat to be got for the money, we can get a very good nourishing meal for very little, if we think of the other things which hold body-making material.

Dried peas and beans have only had the water taken from them and are full of both body-building and heat-giving power. There is a wonderful amount of strength and nourishment in a plateful of nicely made pea-soup, with or without a little bacon in it. A stew with a little meat and plenty of haricot beans is also very nourishing, and is better

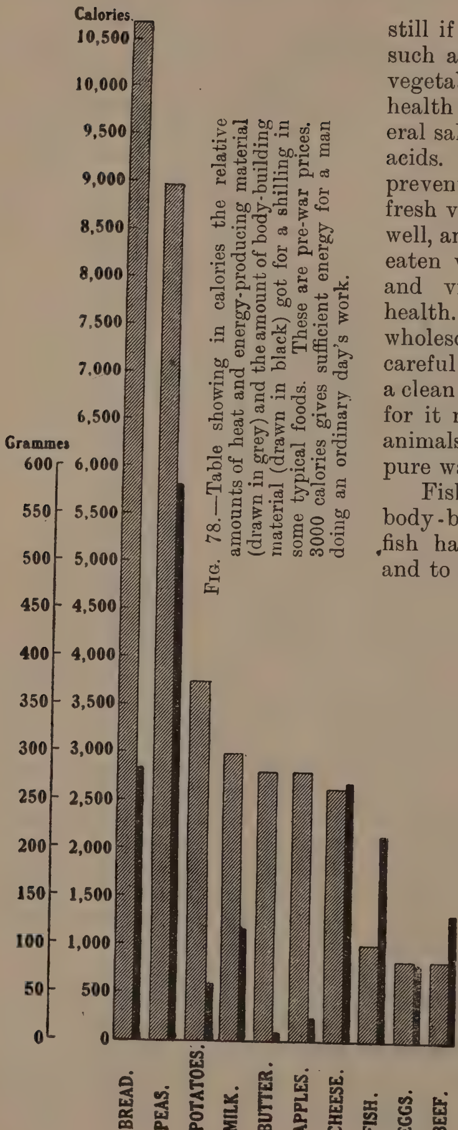


FIG. 78.—Table showing in calories the relative amounts of heat and energy-producing material (drawn in grey) and the amount of body-building material (drawn in black) got for a shilling in some typical foods. These are pre-war prices. 3000 calories gives sufficient energy for a man doing an ordinary day's work.

still if it has fresh vegetables in it, such as carrots or cabbage. Fresh vegetables are very necessary for health because of the valuable mineral salts they contain and for their acids. They purify the blood and prevent skin diseases. We all need fresh vegetables to help us to keep well, and fresh, well-washed lettuces, eaten with just salt, or a little oil and vinegar, are very good for health. Watercress too is very wholesome, only we must be very careful to know that it comes from a clean place and is carefully washed, for it may have harmful germs and animals on it if it is grown in impure water.

Fish contains a great deal of body-building power, but many fish have no oil or fat in them, and to make them a more complete food we eat them with some sort of fat, or butter, or oil, as a sauce. Some fish keep the oily matter in the liver. Cods do this, and from their liver cod-liver oil is made. Salmon, herring, mackerel, and sprats all have their fatty matter distributed through the body, and therefore do not require to be eaten with extra fat, and are not so easily digested as fish like whiting, which has very little oily or fatty matter. Dried fish is all food, as only water has been taken away, and therefore it is a cheap body-builder.

One of the very cheapest ways to get body-building material, however, is from skim milk. Cheap sugar has been a great blessing to people, and gives carbo-hydrate or fuel food, but it will not replace fat entirely. Fat is very necessary to us, especially in winter, and we can get it in many ways: good cream and good fresh butter are the two most expensive ways of all; but nowadays good margarine is practically as nourishing as butter, and is safer and better than poor butter. It used to be more common than it now is for people to give their children dripping with bread, but margarine has largely taken its place. Nevertheless, toast and dripping is both savoury and nourishing.

Suet puddings are good ways of eating fat; and of course the fat of meat should be eaten with the lean. The fat of bacon is easily digested by children, and many children who get colds and coughs and have to take fat in the form of cod-liver oil would very often suffer far less from their colds if they had proper food with plenty of fat in it. Olive oil can be eaten with salads, and the yolk of eggs contains oil. It is far better to buy butter-scotch than to buy and eat the quantities of cough lozenges which some children take to sucking in winter. The lozenges often have some form of opium in them, and should not be taken without a doctor's permission. Butter-scotch is wholesome and soothes the cough, and being made with butter is a very pleasant way of taking fat. But we must remember not to spoil our appetites for body-building food by eating sweets before meals or in great quantities in between meals. Good sweets such as toffee, butter-scotch, or chocolate are the ones which are the best from the food point of view.

A new-laid egg is a thing we all like, particularly when we are quite sure it deserves its name; it is very nourishing. The white is pure body-building material, and the yolk is full also of a body-building material with a special fat in it which is very good for people, and especially good for growing children, as it helps in building up nerves and brains.

Meat is not really necessary at more than one meal; many things can take its place. Maccaroni is made from the gluten of wheat, and therefore is very good body-building material. Oats and milk have been the main food of many a tall, strong Scotsman; and cheese has, weight for weight, more body-building power than meat. A well-known doctor used to say, that to have an example of how cheaply one could live and yet be strong and well nourished, one had only to look at a field-labourer sitting under a hedge and eating bread and cheese and an onion. The bread gave the man his fuel food—his power to do *work*—by the carbo-hydrate it contained in the form of *starch*. The *gluten* in the bread and the *casein* in the cheese gave him all the *body-building* food he needed. The cheese, again, gave him enough *fat*; and both it

and the bread gave him *mineral salts*. Again, the onion, as a fresh vegetable, gave him also valuable *salts*; and if he drank water he obtained all the proximate principles very cheaply indeed.

We pay high prices for delicate things, but it does not follow that they nourish us any better.

Rice is a fuel food, but a rice pudding made with milk is one of the most nourishing of dishes. Potatoes are very useful indeed for their salts, particularly for their potash salts. All vegetables are useful for salts of various kinds, which are most necessary to health. Scurvy was very common in the navy in the days when ships were long at sea and fresh meat and fresh vegetables could only be got at long intervals. Then it was found out that giving lime-juice would prevent it. Nowadays ships have cold-storage rooms, and steamers only stay a short time at sea in comparison with sailing-ships, and scurvy is scarcely known. Eczema too is a troublesome skin disease which sometimes comes from not having enough fresh vegetables. Potatoes are very good food because of their starch and their potash salts. They have not much body-building power, and a good deal of that and the salts is lost if they are peeled. The most economical way of cooking a potato is to boil, or steam, or bake it in its skin, and then it keeps most of its proteids and salts. Other root vegetables, such as beetroots, carrots, and parsnips, have much sugar in them, and sugar is very largely made from the sugar-beet.

Fresh ripe fruit is very good for health, but it is very unwise to eat raw, unripe fruit, or fruit that is over-ripe and decaying, for it may make one seriously ill. Apples are very wholesome, and good in every way, whether stewed, or baked, or eaten uncooked—only, in the latter case, see that they are quite ripe. Dried fruits are wholesome and nourishing; dates, figs, and raisins all contain a large amount of sugar and are very sustaining. Nuts are hard to digest, and need to be very well bitten up. They are nourishing to those who can digest them. They have a great deal of proteid as well as fatty or oily matter in them. Here is a Barcelona nut: I will crack it and take off the shell, and now I will put this lighted match to one end of it. See how it burns like a little candle! That is because it has such a quantity of oil in it.

Cocoanuts are very valuable for their food qualities, and especially for the large amount of fat they contain, from which cocoanut oil and cocoa-butter are manufactured.

We will make a few experiments and see if we can find out anything about some of these foods. We must remember our tests for proteids, carbo-hydrates. and fats. We do not forget that our food materials contain all the proximate principles. Here are some white haricot beans, which have been very well boiled. I will put some into this

test-tube and add a little liquid from this bottle (Millon's reagent). This is the test for proteid which we used when we tested for the gluten in wheat. Do you remember what we had to do next? Boil. Yes, I will hold the test-tube in the flame, turning it round and moving it about, so as to prevent the beans from burning, if any are sticking to the sides, and in order to allow the heat to act evenly. Now it is beginning to boil. What happens? It is turning a deep brick red. What is that a sign of? It is a sign that proteid or body-building material is present. We must not expect so deep a colour as when we were testing the gluten, for the gluten was composed entirely of proteid which we had separated from the rest of the flour, and here we have got the proteid of the beans (legumen) mixed up with other things. As we are testing now we can only judge roughly whether there is much proteid or not by noticing the amount of reagent we use and the strength of the colour we get. Tests to find out the *quantity* of each thing present have to be very carefully and delicately done, and are much more difficult than tests to find out the *quality* of what is present, which is what we are doing now in a simple way.

Let us see if we can find any starch in these beans. We will carry out all the rules for starch-testing as in our previous lessons. Is any present? Yes, they evidently contain a great deal of starch. Now we will crush some up and put them in a test-tube with a little ether, and let the whole stand for a few minutes, and then filter, and put a few drops of the filtrate on a piece of filter paper, and let it dry. Is any mark left? Yes, a greasy mark, which shows that beans contain a little fat. They also contain water and salts, so that they contain all the proximate principles. Beans are therefore a very good food, but they take longer to cook and are not quite so well absorbed as meat.

We have already tested flour from which bread is made, and we found that it contained body-building power and body-warming power; it also contains mineral salts of great value. It is a pity that in order to make flour look whiter some of the most valuable parts of it are taken away, the parts which help to make bones and teeth. Bread made from what is called household or "seconds" flour has more nourishment than the finer flour. Every grain of wheat, moreover, has a separate little part called the germ, from which the new seed will spring (fig. 79). This part is specially full of nourishment for the growing plant, and therefore has much body-building power. It also contains fatty matter, and this makes it apt to turn a little rancid and give the bread a peculiar flavour. But in the old days, when people ground corn between stones, all the corn was easily ground up together, and this germ part was most useful in making rich blood and in causing bones and teeth to grow strong. But later on, roller-grinding came

into practice, and the rollers would not grind the harder germ, which was therefore separated and used for feeding pigs, who throve very well on such food, as can be imagined. The flour which was left behind looked much whiter and finer without the germ, but it was not nearly so nourishing. Later on, people began to realise what was wrong, and ways were found whereby the germ was ground separately and treated in a manner that prevented it from becoming rancid, and "germ breads" were made which contained some of the germ flour, and they are very good, wholesome, and nourishing. Real whole-meal bread is one of the best of all foods, and is really "the staff of life." The Roman soldiers, who conquered the world, lived on whole-meal bread, for they were accustomed to grind their own corn; and it is on record that once they grumbled very much because they were given mutton instead of some of their ordinary food, and that they complained, saying they wanted corn, which was *men's food*, and did not want mutton, which was food "fit only for women and children."

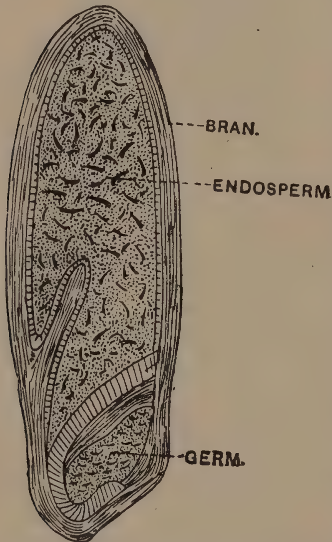


Fig. 79.—Section through grain of wheat showing germ.

Though whole-meal bread is so good, especially as it often prevents people having to take much medicine, and because it is so full of body-building power, yet fine, white bread is more easily absorbed, which is the reason why it is more constipating, just as milk is, which is also well absorbed. The citizen cells in the food-tube do not push the rubbish on well if there is not enough left to stimulate the muscles of the tube by pushing against them.

From all these things we have learnt that although we can get all the proximate principles from food, yet, with the exception of milk, no food contains them in the right proportions to keep us in health. For that reason we take them together, combining those which have much of one thing with those which have little of it but much of something else. Therefore we eat bread and cheese together, beef and potatoes, bread and milk, and Nature has taught us that this is the right arrangement.

Blackboard Summary.

1. Children need more food for their size than grown people, because they are building their bodies.

2. The cheapest kinds of body-building food are dried fish, skim milk, whole-meal bread, the cheaper cheeses, the cheaper cuts of meat, and dried peas and beans.

3. The cheapest kinds of fat are margarine and dripping.

4. Growing children need plenty of fat in their food, and it can be taken in many different ways, such as the fat of meat, fresh milk or cream, butter, margarine, dripping, suet pudding, yolk of egg, bacon fat, etc.

5. Fresh vegetables are necessary for health.

6. Fruit should be eaten ripe. All unripe, over-ripe, or decaying fruit should be avoided.

7. Whole-meal bread is good for bones and teeth, and makes rich blood.

CHAPTER XXVI.

SOMETHING TO DRINK: TEA, COFFEE, AND COCOA.

Necessary Apparatus.

Two teapots or two vessels for making a little tea.
Fire or oil-stove, or else Bunsen burner and tripod.
Two tumblers or beakers of water.
A pinch or two of pure ground coffee.
A pinch or two of ground chicory.

Accessory Apparatus.

A plant and root of wild endive.
Roasted and unroasted coffee-beans.
Freshly ground coffee.
Stale coffee.

WHAT should we do nowadays without tea? We in England drink more tea than is drunk in any other country except Australia, and we should not like to have to pay the price our great-great-grandfathers had to pay. Tea was not known in Europe till 1610, and was sold at ten guineas a pound. In the early days all our tea came from China, but during last century Indian tea began to be very largely drunk in this country, and Ceylon and Indian teas are both much more commonly used now than China tea, which costs more and is more delicately flavoured.

The tea-plant grows in China, India, Ceylon, and Japan. The best tea is usually made from the small leaves at the end of the branches, and the cheaper teas from the larger and coarser leaves. The leaves are dried and prepared in various ways to bring out the flavour. Green tea and black tea are made from the same plant, but the leaves are differently prepared. Tea has been, and is, a great blessing to mankind, for it is a stimulant which helps people to do their work better, and to feel brighter and more awake, and is without the harmful effects which stimulants such as beer, wine, or spirits have. It is worth far more than alcohol to soldiers on the march, for alcohol makes them feel better only for a short time, and causes them to feel more tired afterwards; tea does not depress in this way.

Tea is both a stimulant and a restorative, for it acts on the heart,

the breathing, the nerves, and the muscular system. Like all good things, it can do harm if badly and immoderately used, and can make people nervous, give them palpitation and injure their digestions; but, properly prepared and used, it is a very good thing indeed.

There are a good many things in tea, but the important ones for us to remember are few. First of all, tea contains what is called its "active principle," that is to say, the special part which gives it its peculiar powers. The active principle in tea is called *theine*, and it is theine which refreshes and stimulates. Theine passes out almost at once into boiling water. Another important thing in tea is flavouring matter, which gives tea its pleasant smell and taste; and the third thing is tannic acid. Now, tannic acid or tannin is the kind of thing used to tan hides, and it is not good for the coats of the stomach; it also hardens meaty foods and makes them more difficult to digest. Ordinary tea has about 3 per cent. of theine, but it has 14 per cent. of tannin. The problem is to find out which is the best way to make tea, so as to get out all the good and the least possible amount of the bad. Some people do themselves a good deal of harm by trying to get everything, but the dark colouring matter does no good, and the tannic acid which comes out with it does great harm to their digestions.

Experiments have shown that theine comes out so quickly in boiling water that, after the tea has been made five minutes, practically all the good has come out of it. If it is infused or stewed longer, it looks and tastes stronger, but it is not stronger in the things which do good, but in the things which do harm, for tannic acid keeps on coming out long after theine has stopped doing so.

The Chinese have some very particular rules for tea-making; they say it should always be infused with water from a running stream. The real reason for that is that it ought always to be made with water which has plenty of air in it, and running water has plenty. Has water which has been boiling a long time, or has been boiled up several times, got much air in it? No; the air has been driven off, and the water is flat and insipid. Yet how often do people forget this, and make tea with over-boiled water. As you see, all the time I am talking to you the kettle is heating, and we shall make tea as soon as the water boils. We have now learnt that the water should be fresh and sparkling, and not over-boiled, but it is very important that it should really *be* boiling. A kettle is *not* boiling properly, merely when it begins to sing and bubble, but it *is* boiling when the noisy bubbling ceases and the vapour rushes out.

Another rule for making tea is to use water which is neither too hard nor too soft. It is not good to make tea with rain water, for it brings out too much tannin. Nor is it good to make it with very hard water,

for that does not bring out the good properly, and wastes tea by our having to put more in the pot to make the brew strong enough.

Our kettle is now very nearly boiling, so we will heat the teapot by pouring some of the hot water into it and pouring it out again. That prevents the boiling water from being chilled when it first goes in. We keep the pot very sweet and clean, for the flavour of old tea-leaves will help to spoil a new brew. Now in goes the tea into the clean, warm pot, and there is the kettle boiling hard, so we will pour the boiling water on the leaves and let the pot stand quietly for a few minutes—about three minutes if it is Indian tea, and more if it is China tea. Now we will pour some of it off the leaves into this other clean, warm pot. I will now pour out a cupful; it is steaming hot and smells very fragrant and good. When we have poured it off the leaves, we can keep it as long as we like, with a "cosy" over it to keep it warm. The tea in the other teapot I am going to keep hot and let it stew well.

Some people keep the tea stewing on the hob all day long, adding more tea and more water from time to time, and drinking it whenever they feel inclined. Then they wonder why they get indigestion, flushed faces, and palpitation of the heart. If people want to spoil their nerves and digestions, an excellent way is to drink strong, stewed tea, particularly if they are eating meat at the same meal. Perhaps they sit down to a beef or pork pie and drink strong, bitter tea whose taste is disguised by plenty of sugar and milk. Only people with very strong digestions can stand this sort of thing for long; the others have a bad time with indigestion, and wonder why! The reason is that the tannin in the tea has prevented the gastric juice from being able to digest the meat which has been hardened by it. Strong tannin is very bad for the coats of the stomach and for the gastric glands.

Now let us taste some of this black, strong, overdrawn tea, and without putting any milk in. It puckers one's mouth up and tastes very bitter. It is easy to understand that it cannot do the delicate lining of the stomach any good. If people take no milk in their tea, they usually have to take it fresher and weaker, for they do not like this bitterness. It is wholesome to put milk in it, for that counteracts to a certain extent the effect of the tannin. Tea is not a food; the only food in a cup of tea is found in the sugar and milk. Certainly, however, it is one of the best and most refreshing drinks in the world for grown people, when properly made and used. It is not good for children, as it has too strong an effect upon their nerves and is not good for their growth, and if drunk at all by them should consist of the merest taste in milk or milk-and-water, but it is better for young children not to have it at all. If it is particularly desired to give children something hot, then it is much better to give warm milk.

Coffee is another very useful and valuable drink, and is prepared from the berry of a plant which grows in Arabia, the West Indies, Ceylon, and other places. We do not use so much of it as of tea, partly because it is more expensive, but also because as a nation England knows how to make good tea but usually makes very bad coffee. A great deal of the coffee bought ready ground has much chicory in it. Chicory is the root of the wild endive, and when roasted has a slightly sweet savour, and an infusion of it turns the water very dark brown; but though it is quite wholesome, it has no value at all as a food or stimulant. It has more than double the amount of colouring matter in it that coffee has, and makes the coffee it is used with look much stronger than it really is, and it is very cheap, whereas coffee is rather expensive. As chicory does no harm, it does not matter if people add a little to coffee to make the drink thicker and darker, if they prefer it so, and they sometimes like the slight sweetness of it as well as its other properties. But coffee with chicory in it is not pure coffee and must not be sold as such. The active principle of coffee is *caffeine*, which is the same kind of thing as the theine in tea, so much so that both are very often known as caffeine. Caffeine is so valuable as a medicine that it is extracted from coffee and sold separately, but coffee without it has lost all its valuable stimulating part, though enterprising manufacturers may give it a fine name and sell it cheaply as a "health drink" warranted not to injure nerves or digestion!

Coffee (with the caffeine in it) is a very useful drink for people doing hard work. It acts like tea, but more strongly, and is a very valuable stimulant in fatigue or heart weakness. It is one of the very best things to give if people are exhausted, if they are suffering from cold or shock, and is far better for the purpose than strong alcoholic drink. But, if given for these reasons, it must be strong and pure and hot.

In this country coffee is often made very weak and from inferior coffee, and drunk with a little cold milk added, as if it were tea. To get the full flavour of coffee the beans must have been roasted freshly and ground freshly, and at least two ounces of coffee used to the pint of water. It is made in this country by pouring boiling water over it or just bringing it up to the boil. It contains so little tannin that it does not matter leaving it on the grounds. If the coffee is made very strong and then drunk with a good deal of hot milk it becomes a delicious and nourishing drink. Here is a little ground-up coffee, and here is some ground chicory. They look very much alike. Here are two tumblers of water, and I will sprinkle coffee into one and chicory into the other. Do you notice anything? Yes, the chicory is sinking quickly to the bottom, but the coffee is still floating on the top. It floats longer because it is oily. Do you notice anything else? Yes, the chicory has

coloured the water far more than the coffee has done. Now we will strain the water off and feel the stuff that remains. Do you notice any difference? Yes, the coffee feels hard and gritty, but the chicory is soft and squashy. We can test coffee and chicory in these ways quite easily. Much of the ground coffee sold has got a good deal of chicory in it, and people who want pure coffee must be sure to ask for it, or buy the beans and grind it up themselves. On the Continent people roast and grind their own coffee, and then it is very fragrant and fresh. It is not uncommon in England to ask for a drink of coffee and be given something made with "coffee extract." That pure extract of coffee may exist is not denied, but usually such "coffee" consists largely of chicory. It may make a hot, harmless, and cheap drink, but people who know what good coffee ought to be like, think it very poor indeed, while others like it. "Date coffee" is coffee mixed with ground-up date-stones, and "malt coffee" is coffee mixed with malt; both are weaker than pure coffee.

Cocoa is a safe drink for everyone, as it has very little effect on the nerves, and, made with milk, it has a good deal of food value. Made with water its food value has been much exaggerated. One or two of the cheaper cocoas which thicken very much in the cup have arrowroot mixed with them. Cocoa contains an active principle called *theobromine*, but is not so stimulating as either tea or coffee. While tea and coffee have the effect of preventing sleepiness, in most cases cocoa does not interfere with sleep at all.

Blackboard Summary.

1. Tea and coffee are stimulants without the bad effects of beer, wine, or spirits, but they need to be well made and drunk in moderation, and are not good for young children.
2. Tea should be made with water which is boiling for the first time and has freshly come to the boil. The water should be neither very hard nor very soft.
3. Tea should not be stewed on the stove or the hob, nor should it stand long on the leaves, for that draws out the tannic acid, which injures digestion.
4. Overdrawn tea and too much tea are bad for nerves and stomach.
5. Strong coffee is a stronger stimulant than tea, when pure and well made.
6. Tea and coffee cannot build up the body.

CHAPTER XXVII.

FERMENTED DRINKS.

Necessary Apparatus.

A glass jam-jar of 2 lbs. capacity, containing one ounce of brown sugar, about a third of an ounce of flour, and half a pint of lukewarm water. These must have been well stirred together, and a little compressed yeast added and stirred in with the rest. The whole must have been left in a warm place and well covered for some hours previous to the lesson.

Another glass jar prepared with contents as above, but not long before the lesson.

Wire.

Small basin or cup to hang inside the jar.

Limewater.

Pipette. Ordinary glass tubing can be used instead, or a fountain-pen filler.

Accessory Apparatus.

Other experiments can be added if desired. Ale can be boiled in a flask until the alcohol is driven off at the mouth, when it can be lit with a match. The effect of alcohol on albumen can be shown also.

We have been talking about various kinds of drink, but we have not yet spoken about the kind known as "fermented" or "strong drink."

Here is a glass jar which once held two pounds of jam; some hours ago I put into it an ounce of brown sugar, about a third of an ounce of flour, and I poured on to them a big tumblerful of water with the chill off, then I stirred them all up together. It seemed a little too thick and gluey for what I wanted, so I added a little more of the lukewarm water, and then I took a little compressed yeast, stirred it well in also, covered the jar up, and put it in a warm place where the temperature was about 74° F., and there I left it for some hours.

Now I want you to look carefully. What do you see? The liquid in the glass is bubbling and moving. Bubbles keep coming up to the top and bursting. Smell the inside of the jar. What is it like? It smells rather like beer. Here is another jar which I prepared a little earlier than the one I have just shown you. What do you see? No

bubbles at all. No; they have been there, but have now stopped. We will light this taper and take the cover off this last jar and put the taper down into it. What happens? The taper goes out. Do you remember our experiments on air and how we proved, when a light would no longer burn under a glass, that the glass had carbon dioxide gas in it. Shall we try to find out if that is the case here also? Here is a little cup round which I have fixed some wire, and I have twisted the wire at each side to form very long handles so that each handle has a little hook at the end. Now I will lower the cup into the big jar, and hook the wire on to its edge so that the cup hangs inside. I will cover it up and leave it for at least half an hour. You must remember that I had in the jar sugar, water, and yeast. What has been happening is that the yeast began to grow in the warm, sugary water, and as it grew it altered the sugar by causing the atoms of the elements of carbon, hydrogen, and oxygen in the sugar molecule to change their places. Some fly off together as carbon dioxide gas, others stay behind and group themselves differently from the sugar atoms, making a new substance which is called "alcohol." Alcohol, made by the yeast plant out of innocent sugar, is a very useful thing in many ways in manufactures and medicines, and is used also by many people as a drink. But when it is wrongly used, it becomes one of the most deadly poisons, for it ruins both mind and body, and causes untold suffering, misery, and disgrace.

The yeast plant is found in dust and carried by the air. It clings to the skin of fruits and can grow in their sugary juices. It is in this way that wine is made. The grapes are gathered and put into big vats and crushed up. The yeast cells get into the juice and begin to change the sugar into alcohol and gas, and the gas bubbles up into the air. If the juice is very sweet a large quantity of alcohol will be made, but after a certain amount (about 14 per cent.) has been produced the alcohol becomes too strong for the yeast cells and kills them. The rest of the sugar remains untouched.

Beer is made in a different way. Barley is used; the grains being kept warm and damp until they sprout. As the sprouting begins, most of the starch in the grain changes to sugar. The sprouting is then stopped by heating the grains, and they are ground up and put into water. As the grains soak in the water the sugar is dissolved out, and yeast is added to it and begins at once to change the sugar into alcohol. The bitter taste of beer is given to it by adding hops. Nowadays, however, a good deal of beer is made from starch turned into "invert" sugar by the use of sulphuric acid. Beer contains from 5–10 per cent. of alcohol.

Spirits contain more alcohol than 14 per cent., because they are

made by distilling liquor which has already been fermented. Distillation separates the alcohol from some of the water, and the distillate, or part which has been driven off, can be distilled over again and more water separated from it. Pure alcohol is very strong indeed, and brandy contains about 50 per cent. of it. Natural wines cannot, as we have seen, contain more than 14 per cent., because the yeast plant is killed by that amount, but some wines, such as port and sherry, have alcohol added to them, and are known as "fortified" wines. In this country a large quantity of strong wine is made which never pays duty, because it is manufactured from imported "must." Must is the condensed juice of grapes, and much wine is made from that and from dried fruits, such as currants and raisins steeped in water and allowed to ferment. Such wines are afterwards mixed and flavoured to resemble port, claret, and burgundy, and can be sold very cheaply. Some of the so-called port has as much as 25 per cent. of alcohol in it and is a very strong drink. Unfortunately, many people seem to have the idea that port is a temperance drink; and as this kind of port can be bought very cheaply and is largely sold by public-houses, every one ought to understand that in taking it they are taking *strong drink*, far stronger than most drinks. Brandy is supposed to be made from wine, and cognac is the French name for it, from the district where it was originally made; but the best brandy in France is called "*fine champagne*," because it is made from the same grapes as those used for making that wine. The greater part of the brandy that is sold is, however, made from fermented potatoes or malt. Whisky is made from malt or potatoes, and it contains, as does brandy, about 50 per cent. of alcohol. Rum, which contains about 40 per cent., is made from fermented treacle. Gin is made from malt and barley, but has various aromatic oils added to it, such as oil of juniper and oil of turpentine.

None of these drinks have any real food value, though they are food *sparers*. Beer and the sweeter wines have the food value of the sugar they contain; that is, they have about as much as sugary water.

We will now go back to our little cup hanging inside the jam-jar. In this pipette I have limewater, which, as you see, is clear. I will now empty the limewater out into the cup. What happens? The limewater turns milky. Why is that? Because carbon dioxide gas has filled the cup. We learn from this that yeast cells, growing in sugary liquid, destroy the molecule of sugar, and turn it into a substance known as alcohol and into carbon dioxide gas.[1] This process is one of the ways in which "germs" destroy matter, and it is called fermentation. Can you tell me the other methods? Yes, decay and putrefaction.

[1] When sugar is fermented the change is represented by the following formula:— $C_6H_{12}O_6 = 2(C_2H_6O) + 2(CO_2)$.

So we see that fermentation is a destructive process. Cane-sugar does not ferment unless turned into an invert sugar by being boiled with an acid; but yeast ferments glucose or grape-sugar as well as other things.

Alcohol is classed by chemists as a poison, but it is of great use in many ways, just as other poisons are. It is not nearly so much used in the practice of medicine as it used to be, for it is now recognised that, though at first it is a strong stimulant, it brings on a reaction afterwards which may lower the person's powers so much as to do harm. Its place has now been largely taken by other stimulants which do not have the same harmful after-effects. As alcohol passes very rapidly through the walls of the stomach and so gets into the blood, it may save life in conditions of great exhaustion and shock, but it is the greatest mistake to fly to brandy and other similar stimulants whenever anything is wrong, and a very great deal of harm is done by doing so.

Another very common mistake is to think that drinking strong drink keeps out the cold. As a matter of fact it does just the contrary. Why is this? *It is because alcohol is a nerve and protoplasm poison.* We have learnt about cells, and we know that the foundation matter of life is protoplasm. *If a cell is placed in alcohol it hardens and dies.* If a very small amount is present, the cell shows increased response or irritability; a slight increase in the amount dulls its sensitiveness, and a large amount paralyses and finally kills it. We can see this in cases when people have taken too much strong drink; they first become talkative and excited and perhaps quarrelsome, then they become dull, heavy and stupid, and then insensible, and in extreme cases may go on to death. The more highly developed the cells are, the more quickly are they likely to be affected by it. Let us see what this has to do with the idea of its being able to keep out cold. What organ in the body have we learnt to look upon as the great heat regulator? The skin. Yes; how does it keep the blood at an even temperature? If the outer air is very hot a message from the skin nerves takes the news to a nerve centre in the spinal bulb. From that centre a message is sent down through other nerves which control the size of the blood-vessels (vaso-motor nerves), and the vessels become larger, and more blood comes to the surface to be cooled by contact with the outer air and through perspiration evaporating from the skin. In this country the outer air is nearly always very much cooler than the blood. If, on the contrary, the message is that the outer air is bitterly cold, then the surface blood-vessels are ordered not to allow much blood to get into them, and so it stays below in the warmer parts and does not get chilled. Now, although alcohol burns in the body and gives off heat as truly as sugar, it also paralyses the nerves controlling the surface blood-vessels, so that blood comes to the surface, no matter how cold the outside air is,

giving a sensation of warmth to the drinker, but chilling the blood at the same time. For the heat produced by the alcohol burning in the body is less than the heat lost, and, no matter if the outer air be warm or cold, the surface blood-vessels remain wide and full of blood because their nerves are partly paralysed for a time. Where are the nerve-endings that tell us about the temperature? In the skin. They are therefore bathed in the warm blood and bring up a message of warmth and comfort to the brain; *but they are being made to deceive the brain*, for in reality the outer air may be deadly cold. That warm blood goes on its round or circulation *just a little bit colder than it was* when it came up, and after a short time it reaches the surface again and gets *a little more chilled*; but all the time it bathes the nerve-endings, and they tell the brain of warmth. So it may go on until all the blood in the body has been chilled to a dangerous point, and in such a case the body cells are not able to resist the cold air, and the person may get seriously frost-bitten, if he is out of doors in frosty weather, or he may suffer from inflammation of the lungs or bronchitis from an exposure which would not have been felt by a man who had not been drinking. One of the first things that has to be done in dealing with some unhappy person who has become insensible from drink is to warm him, for he is deadly cold. In Arctic expeditions alcohol is either not used at all or with the very greatest care, for it is well known that it makes the cold more severely felt and leads to frost-bite.

After long and exhausting exposure to cold and wet, alcohol may be of service in restoring the circulation when the blood is driven out of the skin, and the organs are congested, and the heart is acting feebly, but the person must be kept warm after taking the spirits. A man coming in chilled and wet, who instantly flies to spirits to warm him, is acting very unwisely indeed. Hot soup, hot coffee, hot tea would warm him equally well and do him no harm afterwards.

Does drink make it easier to do work? The answer depends on whether we mean a short, sharp effort or a longer piece of work. The first effect of alcohol is that of a stimulant: it whips up the energies of the body as a whip rouses a horse. Nature keeps a reserve store of strength in the body, and owing to that reserve a man who is very tired can quickly recover after rest and food. But if that same man has been compelled to go on and work long after he was exhausted, then his reserves of power are called upon and the body cells may be so used up that in extreme cases he may die of exhaustion, or not recover his health and strength for years, and perhaps never. Now, drink dulls the warning feeling of being tired, and enables a person to go on long after he ought to stop, and so he uses up reserve strength. Moreover, to return to our question as to whether alcohol improves work,

we shall find that since it acts as a stimulant in small quantities at first, it may make the person able to put forth a great effort and do a short, sharp piece of work more quickly, but it means that his reserve strength is soon used up, the rest of the work will be done with difficulty and he will be very tired afterwards. This is so well known, that in training people for hard work or any great effort or feat of endurance no alcohol is allowed. There is no doubt whatever that people can do as hard work, and even harder, without alcohol as with it, and that they do not suffer from exhaustion afterwards in the same way. On the famous forced march to Kabul, Lord Roberts stopped all alcohol. In brain-work requiring care it is found that far more mistakes are made when alcohol has been taken. *Alcohol, then, does not improve the power to do prolonged or accurate work.*

Strong drink should never be given to children. All young cells are very easily damaged by it. Experiments have shown that, when puppies were fed on food with alcohol in it, they developed badly and were dull and heavy compared with puppies from the same litter who had had none. Alcohol is very harmful to the young brain cells and ruins the nervous system.

There was once a French Canadian who had a gunshot wound which left a hole, opening into his stomach, and through this the doctors were able to see how the stomach worked during digestion. It was noticed that whenever he took alcohol the lining of the stomach became much redder; and when strong spirits were taken, little ulcers appeared on the walls, about which the man knew nothing, as pain is not felt as a rule by the coats of the stomach. The citizen cells composing the stomach do not inform the brain of all that is going on, for it would be very uncomfortable for us if we always felt the strong, churning movements necessary to mix up and grind the food; therefore the cells trust the cells of the tongue to find out if the thing is safe to swallow, but people swallow strong burning spirit in spite of the warning their tongue and mouth give them. It is a great mistake to think that because the burning is not felt as soon as the drink gets into the stomach it does not burn the walls of that organ as much as it would have burnt the skin of the mouth if it had been held a little time in it. Mucous membrane is shrivelled and whitened by the use of strong spirits, and the habit of taking "nips" is very harmful, especially when the stomach is empty and the spirit does not soak in to any food, but lies on the mucous membrane and burns and injures it. The constant irritation of frequent spirit-drinking on an empty stomach has led to the death of many a man from lingering and painful diseases. A little alcohol taken during meals may sometimes help digestion in certain cases of ill-health, and also a very small quantity of well-matured brandy or old

whisky is sometimes ordered for special reasons, because in addition to alcohol there are certain ethers in *very* old brandy; but although alcohol, as a rule, should, if used at all, only be taken at meal-times and with the greatest moderation, yet it is not in the least necessary for healthy people, who are better without it.

Much alcohol taken with food hinders digestion, and constant and heavy drinking ruins it.

Alcohol itself needs no digestion, and as soon as it gets into the stomach it begins to soak through into the blood. If more is taken at one time than can be burned up by uniting with oxygen, then it circulates in the blood and is carried to every part. Let us think what this means. The lymph or nourishing part of the blood passes out through the walls of the tiny capillary blood-vessels in order to nourish the cells among which it finds itself. The blood, in short, brings food and fresh air and *a little alcohol.* Now, we have just been learning that alcohol destroys cell life, or at least deadens and paralyses it. The human body can only oxidise a very little alcohol at a time, and the rest must go to the cells. Since the effect is to dull and deaden them, they are not able to profit properly by the food and air brought to them, nor can they properly get rid of waste matter. The result of this interference is shown in all sorts of ways: poisons are formed which injure the organs and the blood, and the body cells themselves may be so interfered with that they alter and degenerate and become fatty. This is a very serious state of things, for a cell which has become altered into fat will never be the same vigorous cell again. Fatty degeneration of the heart may be caused by other things than drink, but drink is a very common cause of it. Do you remember how strong and firm the muscle of the heart was found to be when we had our lesson on it? It is in a very different state if it has been injured by strong drink, and it is no longer in a fit state to do the extra hard work it is called upon to do; for it has not only to work at a greater rate, but it has to work much harder, as it has to drive the blood through arteries which are no longer soft and elastic and able to help in pushing the blood on, but through ones which have been hardened by the irritation of drink and are probably narrow and brittle.

Too much strong drink has a very marked effect on the liver, which has to receive it first. The irritation at the onset has the effect of enlarging the organ, but later on the cells may be so altered that they become like fibres, and as they tend to become shorter, the other cells become squeezed and strangled, and in time the whole liver gets hard and lumpy-looking, as if it was studded with large nails. A liver in that condition is known as the drunkard's or "hobnailed" liver. Naturally, of course, it cannot do its work properly. These are bad cases caused

by long years of hard drinking. But when we come to consider the effect of drink on the brain we seem to see its evil effects most clearly. We have learnt something about the wonderful work of the brain cells in the cortex or grey matter of the brain. We learnt that millions of cells exist in the cortex and that they are in touch with each other by means of fine branches, and also that they send out a long fibre, which presently gets a sheath round it and joins with other fibres to form a nerve (see fig. 54, p. 98). These nerves form a vast system, like the telegraph system of a big town, which enables messages to be sent to all parts of the body, the central office being the brain. We remember what the powers of life are, and that, with few exceptions, all the cells in our bodies possess them all. The power of response to a stimulus is the one which the brain cells have especially developed as their particular work, and to enable them to do it properly they require a very large and very pure blood supply. They possess the power of taking in food and building it up into their own bodies and breaking it down in doing work as all living cells do, but they have given up the power of splitting and reproducing themselves. The young child is born with the same number of cells that he will carry with him to his grave as an old man. If they are destroyed, they can never be renewed. If they are damaged, the records of memory that they keep are damaged also.

To these delicate, highly specialised cells comes a strong thing like alcohol, and irritates and injures them. Alcohol, circulating in the brain, also means that the lining of the small blood-vessels is injured, and in that case also waste matters do not get away as they ought, but remain and poison the brain, and therefore poison and injure the *mind.* Sometimes parts of the brain are cut off from proper nourishment, and the cells and fibres deteriorate very quickly. In cases such as these, the man or woman can no longer think, or feel, or act as reasonably or wisely as before. The nerve cells, bathed in alcohol, suffer especially. The communicating fibres or branches become beaded or broken, and the memory is weakened. Memory does not only mean memory for *things*, but it also means memory for *morals.* The drunkard often changes his whole character as he sinks on the downward path. The kind father, the good husband, the son or brother of whom every one of the family was so proud, the mother who loved her children, become sadly altered. Money is spent on drink which should go for food and clothing, work is neglected or badly done, and the whole family suffers. We must never forget that drink weakens self-control, which is one of man's noblest possessions.

The highest and finest part of the brain is the one which is affected first, either in a drinking bout or in chronic alcoholism. As a person drinks, the first effect is that the heart is made to beat more quickly,

therefore more blood comes to the brain. Ideas seem to flow more rapidly, and the first stimulating effect is felt. The fore-part of the brain is the organ of intellect, self-control, reason, and judgment, and is the latest developed and the most sensitive. It therefore feels the stimulating effect strongly, and at first seems to work quicker and more brilliantly. The next effect, however, is that of a narcotic; the cells are slightly stupefied and reason and judgment become a *little dulled*, just as the other parts are beginning to feel the first stimulating effect. The result is that the inclination is to talk and move, but the talk is not so well controlled, since reason and judgment are stupefied. The person therefore is liable to say foolish things and to betray secrets. Later on, the centres for movement which have been strongly stimulated are in their turn stupefied, and the person no longer speaks clearly or walks straight. If he persists in drinking, he reaches a stage when the centres are quite deadened and he becomes unconscious. Were he able to go on he would end in paralysing the centres for breathing and for controlling the beating of the heart, which are already affected, and he would die. This sometimes happens when a large quantity of spirits has been drunk in a very short time, sometimes for a foolish and wicked bet. In such a case the person may die after a few hours, or in some cases after a few minutes.

Our great poet Shakespeare has said:

> "O, that men should put an enemy in their mouths, to steal away their brains!"

As a rule, the hard drinker destroys his powers of brain and body by degrees, and one of the most harmful ways of drinking is to be always drinking and never drunk. Such people often call themselves "moderate drinkers." In reality they often take far more drink than a man who gets more blame because he sometimes exceeds and shows himself to be tipsy. It is true that we cannot lay down a hard-and-fast rule for others, for what does not apparently affect one person at all may affect another very strongly. Most people do not need alcohol at all, and would be much better without it, while in the opinion of some doctors the smallest amount is harmful.

Our lunatic asylums are full of people of whom a large percentage are there through drink. As a nation not only do we lose the value they would be to us as useful sane citizens, but we have to pay strong, clever, sober people to do nothing else but look after them. Think of the army of doctors and nurses, policemen and warders, who have to be paid, largely because people cannot rule themselves and keep away from a disgusting and degrading vice! And we must not be content merely to condemn—we must find out *why*; for bad houses, poor food, irregular work, pain and suffering and ill-health, are all things which make it

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easier for people to take to drink to make them forget their sufferings and troubles. It is the duty of a great country to put these matters as far right as possible without fear, and to educate itself in ideas of self-respect and self-control. Bad houses may make bad people, but bad people will make bad houses out of good ones.

It is difficult to say how much of the insanity in the country is due to parents having drunk heavily and, after ruining their nervous system, passed on a bad inheritance to their children; or, on the other hand, how much of the drinking is due to nerve weakness in the first place. But this is certain, that people of weak will should never touch alcohol, nor people with a history of nervous disease in their family. For both of these it is a deadly peril.

To learn self-control is one of the great aims of true education, and the time to begin the practice of it is in youth. Let us learn early to scorn to love slack and easy ways. It is a good plan during the day to do something just because it gives us trouble and the lazy part of us would rather not do it. So also it is a good plan to resist small temptations; to give up some little selfish action, some bit of bad temper, even if it does not seem to us to be very important. *It is the little things that count in the day of the big temptation.*

Blackboard Summary.

1. Yeast growing in sugary liquids produces carbon dioxide gas and alcohol. This process is known as fermentation.
2. Alcohol is first a stimulant and then a narcotic, and is a nerve and protoplasm poison.
3. Alcohol is not necessary for people in good health, and should be only very rarely used in illness, and by the doctor's orders.
4. The effect of strong drink is to lower the temperature of the body and to make it more easy for germs to attack it.
5. Strong drink is responsible for an enormous amount of poverty, misery, insanity, and crime, and excessive drinking ruins mind and body.
6. The power of self-control distinguishes men from animals.

CHAPTER XXVIII.

WATER.

Necessary Apparatus.

A tall jar.
Spirits of turpentine (a few drops).
Test-tubes. One very large one is advisable.
Water.
Cup.
Two watch-glasses or very shallow vessels.
Lamp.
Tripod.
Sand-bath.
Some crushed ice.
A thermometer.

Additional Work.

Testing hard and soft water with soap test.
Experiments on cultivation of bacteria from pure water and polluted water with nutrient gelatine.

The first thing that I am going to do to-day is to prepare a little experiment which we shall use very soon. Here is a jug of pure, clear water. I will pour some of its contents into this glass, and one of you can taste it and tell us whether it is fresh and good. Into the bottom of this tall jar I will pour one or two drops of turpentine. This clean test-tube I will fill nearly full of the clean water, and then lower it carefully into the jar until it leans against the side. I will now put a cover on the jar and set it aside for a little.

We have heard a good deal about water during these lessons. Indeed, we are beginning to feel that water and many other things turn up in the most unexpected places, and behave as we never expected them to behave. We found that our solid bodies were mostly made up of water, and that was a great surprise to us, for it is hard to realise that if a man weighs 154 lbs., 111 of them will be nothing but water! We found out that some parts of the body were very watery and others much less so. When we studied food we found water there, and learnt that three-quarters of a beefsteak, solid as it seems, is made up of water. Vegetables, we found, were more watery still. The fact

is that water is everywhere, and is so necessary to life that even germs cannot grow without it. It covers over three-quarters of the globe.

I am pouring a few drops of water into this watch-glass and setting it on this hot sand, which I heated in a metal dish called a sand-bath, over the flame. If that had been inconvenient, I could perhaps have put it on a warm stove.

Here is a large test-tube, and here is some ice which I got from the fishmonger and have just crushed up very small. If it were winter weather I might get the ice from a pond, or use snow. I will fill the tube nearly full of the crushed ice, pressing it well down and adding a little water to fill up the crevices. We will put a mark on the glass to the exact level of the ice. This ice is just beginning to melt, and we will take its temperature with a thermometer: 32° F. or 0 centigrade. That is just freezing-point.

Now we will take out the thermometer and gently heat the test-tube by the flame, till the ice is all melted. It is a very long time melting. Is the water which is now in the tube instead of the ice standing at the same height as the ice stood at? No, it is much lower. If we froze the water again the ice would be back at the old level. So it is evident to us that water takes up more room when it freezes. That is what happens in a water-pipe in cold weather. The water inside freezes, and is so strong that it can burst the pipe in trying to get room to expand. Perhaps the break in the pipe is not found out at once, if the frost is severe, and the water remains firmly frozen, but when the thaw comes—and in this country it may even come the same night, so changeable is our climate—then there is great trouble, for the water from the burst pipe makes a terrible mess. We have to be careful to put pipes where they will not freeze easily; we should have them protected, and in case of danger of freezing we can cut the water off from that part and see that the pipes are empty. We do not want to waste water if we can help it, so that plan is better than letting the pipes run gently so as to keep the water moving, which will probably prevent it from freezing. Sometimes, however, we are obliged to use this wasteful plan.

We will take the temperature of this just-melted water. What is it? 32° F.! That is surely very odd, for it is the same temperature as the melting ice, and we held the ice in the flame such a long time to melt it and must have used a lot of heat. What has become of that heat? It has been all used up just to melt the ice, but it is lying, as it were, hidden in the water—"latent heat" such hidden heat is called. When water freezes, heat is driven out of it; but as long as that heat which we put into the ice in order to melt it is only sufficient to turn it into just-melted water, then we cannot measure it in the ordinary way. In a thaw the frozen water is taking its proper store

of heat slowly out of the air—that is to say, it is taking up the amount of heat without which it cannot remain liquid. In a frost it is giving up its heat slowly to the air. This fact is a very important one for those who live in very cold countries, for if, when the air began to get warmer in spring, all the ice and all the snow melted at once, then there would always be the most terrible floods. But, as we saw, it takes warmth a long time to melt ice.

We have already learnt, when we were talking about air, that the boiling-point of water depends upon the pressure of the atmosphere, and that, if we go up a high mountain, water will boil long before it has absorbed the 212° F. of heat (or 100° C.) necessary at sea-level to make it boil. We also know that it takes more heat than that to make it boil in a deep mine, where the air pressure is greater. So, already, we know something about water.

Let us now look at our experiment. I will uncover the jar, take out the test-tube, pour the water out into this cup, and ask one of you to taste and smell it. Is it as good as it was before? No, it smells and tastes strongly of turpentine! Yet the turpentine was right at the bottom of the jar, far away from the mouth of the test-tube. What does this experiment show us? It shows us that water can easily absorb smells and gases, and be tainted by them, and therefore we learn that we must be very careful about where and how we store water so that no evil smell or gas can come near it. When water is supplied by pipes to a house it is usually by what is called the "constant system," which means that the pipes are always full. That is very convenient and it is also safer, for it means that the pressure of water in the pipes is greater than the pressure of the air outside them, so that there is no danger of bad air from the soil, or from a leaking gaspipe, or from a sewer getting in through a crack. When the supply is not constant, as in what is called the "intermittent system," the pipes will be empty of water at times and the pressure of air outside the pipe may be much greater than the pressure within the empty pipe, so that bad air may easily get in by a crack or a bad joint, and then next time the water comes into it and it runs full it will take up, perhaps, some impure gas from that air. It is also possible for impure liquids from leaking drains to be drawn in. Another good point about a constant supply is that there is no need for cisterns in which to store the water in the house, for use when the water is cut off, as is the case with the other plan, for it is only rarely that there is any need to cut off the water at all, while in the intermittent system it may be cut off for the greater part of the twenty-four hours every day.

A cistern for water should be put in some place where it can be got at easily and cleaned. It should have a cover to prevent dust, dirt,

and animals, such as insects or mice, from getting in. Cisterns should be made of good hard materials; slate is used, and iron, enamelled or cemented. Lead is not good, because soft waters dissolve it, and lead is a poison. Drinking-water cisterns must be ventilated by pure air coming into them, and they must have a pipe near the top through which the water can flow out if the cistern gets overfull. This overflow-pipe must be taken through the wall to the outside of the house and cut off. If the cistern gets too full, from the stopcock not acting properly, there is no waste of water by this plan, because, if people see water pouring out from the overflow pipe, they stop the mischief at once; but if the overflow pipe is carried into some other pipe there may be very great waste before things are set right. We will look at some cisterns and notice these things for ourselves.

Here is the watch-glass which I filled with water. Is there any change? Yes, the water has dried up—"evaporated," as we say. The warm air has taken it all up. That gives us another health lesson, for drain-pipes are bent at certain places in order that they may hold water constantly there to prevent drain or sewer air from coming into a house. These bends are called "traps," and we shall learn more about them presently. Now, if water can evaporate in warm weather and even in cold, it shows us that traps which are not often used may go quite dry unless water is poured into them. In hot weather the traps in the gutters, known as street gullies, and also the gullies in yards, ought to be flushed out from time to time. Unless we do so the trap may dry up and then bad air can pass up it.

Water, as we have already learnt, contains air which it has dissolved, and it can dissolve such things as salt and sugar and many other things as well. It has, in fact, such wonderful powers of dissolving that it is never found without something in it, though that thing may be quite pure and harmless.

Life would be impossible for us without water. People have lived many weeks without food, if they had water to drink, but they die very soon without water. We need it for drinking and clearing impurities out of our bodies, for washing ourselves, our clothes, our utensils, and our houses. We need it for drains and sewers, for watering the streets, for public baths, for the putting out of fires, and for the cleansing of many things. We need it for animals, we need it for manufactories, and we use its force to drive machinery, make electricity, and grind corn.

Where does the water all come from, and where does it all go? The sun is the great drawer of water. It is a furnace drawing moisture from the sea and the land and storing it in the air. We see it condensed to fog or vapour in the form of clouds, and it returns to the earth as

rain, snow, or dew. All water, therefore, may be looked upon as rain-water. What fills the ponds? Rain-water, which has run into them off the ground on which it fell. What fills the wells? Rain-water, which has soaked into the soil and bubbled up in springs. What fills the streams? Rain-water, running over the ground and finding convenient channels to run in. Where does the water of the deep springs come from? Rain-water, which has soaked deep into the soil, perhaps miles away, until it has got down to rocks through which it is unable to pass. It then runs along, or soaks its way along, the top of the rocks, possibly getting to some part where there are hard rocks above it, so that it may be imprisoned above and below. Finally it may come to some crack or fissure in the soil and bubble out in the form of a spring. Such a spring may be the result of rain falling on hills very far away. All this water finds its way gradually to the sea, and the sea also is rain-water. But the sea is salt, you say, and rain-water is not salt at all! Why is this? We learnt just now that water dissolves things so easily that, from the chemical point of view, it is never found pure. River water coming down to the sea brings with it various salts washed out of the rocks. These salts are left behind in the sea-water when the sun draws up vapour from it. Rain, coming down through the air, takes up carbon dioxide gas from it, and washes down dust and seeds and germs of plants floating in it. After snow or rain has fallen, the air is washed very clean and pure, and we often notice how deliciously fresh and pleasant it is. Rain-water in towns is very dirty, for it has to wash dirty air and dirty roofs and gutters. Rain-water is distilled water, distilled from other water by the sun's heat, and all mineral matters have been left behind. So from the water of the salt sea the sun can take pure, soft water and store it in the air, whence it will in time fall to the earth in the form of rain, and once more pass into the sea.

Rain-water is economical with soap, for it makes a lather with it very quickly. Water with much mineral matter in it is extravagant with soap, for soap cannot lather with it until it has combined with the minerals, and therefore much may be wasted.

We have learnt a little about how water dissolves mineral salts. Let us consider more fully what happens when rain falls. Rain-water, containing plenty of carbon dioxide washed out of the air, falls to the ground and soaks in and also runs along the surface, washing away with it dirt and dust, together with insects, germs, and seeds. It may flow over land which has been manured, and in so doing it carries some of this impure matter along with it, together with other impurities, and washes it into the streams and ponds. Streams are channels into which the rain has found a way or which it has made for itself; ponds

are hollows filled up by the rain and sometimes also fed by springs. Next time you see a storm of rain, notice where the water goes and what it is washing along with it, and you will understand why pond, stream, and river water is already different from rain-water. Ponds, streams, rivers, lakes, and shallow wells are all in touch with the air, and are, on that account, known as "surface-waters." We see that it is very easy for surface-water to be far from pure, but in the case of large rivers and lakes the water gradually becomes purer, and lake-water is often very pure and good. River-water is purest where it runs strongest. Water-plants in rivers help to purify the water, and so do those germs which are friends to man, for they get rid of harmful animal matters by altering them into something harmless, and they prevent the growth of evil germs. Surface-water is not so safe as underground-water, for it is always possible for impure matter to get into it; but where it is used for drinking people take care to protect it and to keep sewage and dirty matter out of it, if they are wise. If we do not feel sure that the water we drink has been kept pure, or purified if it was not pure originally, then we ought to *boil* it before we drink it.

"Ground-water" is rain-water which has sunk deep into the soil and accumulated on some layer or stratum through which it cannot pass; it is not in touch with the atmosphere. It may take up carbon dioxide gas from the air in the soil and dissolve lime out of the rocks as it travels along, forming carbonate of lime. It dissolves magnesium, and forms carbonate of magnesium, and collects other minerals as well. In some places the water takes strong salts from the rocks through which it passes, and these salts are good for certain diseases. Some waters have iron in them, and others again are so full of common salt that brine baths are established where they are found, to cure rheumatism.

When rain first starts to pass through the soil, it washes down dust and germs; but if it reaches clean soil and cannot get further down on account of some layer which stops it, then it runs along the top of the layer, and the rocks or soils it passes through act as a filter, and by and by all germs and dirt are left behind. Such water may be clean and pure and yet have so much mineral matter in it that when used with soap it uses up a very large quantity before it can be got to lather. But for drinking it may be delicious to the thirsty person, for it is fresh and cool and full of air, and very pure and free from germs and dirt. Water with much lime and magnesium salts in it is called "hard water." Sometimes a well or deep spring yields water so hard that it disagrees with the health of the people drinking it.

Water from deep springs is usually looked upon as the purest of all, and next to that comes water from deep wells. Both these waters have

few or no germs in them. Then next again in purity comes water which consists of rain fallen on the soil of clean hills far away from houses and manufactories. This water is collected on the hillside by being made to run into big reservoirs, where it is stored and then sent out by pipes down to the towns and villages below. Such water, coming from the uplands as it does, is called "upland surface-water." It is very soft and pure. Any little impurities it may have sink to the bottom during its rest in the reservoir. Many of the splendid water-supplies of our big towns come from distant hills, and the water is carried for many miles in pipes. Upland surface-water is very good for manufacturing because of its softness.

River-water is generally safe if no sewage enters it, but it is dangerous if sewage goes in and if it is drunk without very special methods of public filtration or without being boiled. Many towns are obliged to take their water-supply from rivers which are not pure, but if they are wise and enlightened people they make laws to try to keep the water as clean as can be managed, and they arrange to have it carefully filtered. There are many places in the world where terrible outbreaks of typhoid fever and cholera occur because the people drink polluted river-water.

Rain-water, as a drink, should be always looked upon with suspicion, for it is apt to contain dust and dirt washed down from the air and off the roofs from which it is collected. It may also contain insects and decaying leaves out of the roof gutters. If it is used for drinking, as it sometimes must be if nothing else can be obtained, then it must not be stored in a cistern which can pollute it; also it should be boiled and filtered before being drunk.

Water from shallow wells is as a rule dangerous. The difference between a so-called "deep well" and a so-called "shallow well" is not so much one of depth as one of *position.* The upper part of the soil is soft and porous, and rain sinks down into it until it comes, as we have seen, to rock or soil through which it cannot pass. The various layers of soil are called strata, and each separate one is a stratum. As a rule, strata lie unevenly one over the other. The porous top, or surface soil, may become very full of water, sometimes to within a very few feet of the top, sometimes right up to the top, and then we say the ground is *marshy.* As a rule, however, this porous layer is deep, and the water in it lies several feet below the surface. Engineers call a well a "shallow well" if it is sunk no further than this porous soil, though if the layer be a thick one it is quite possible that the well may be fairly deep in the ordinary sense. A "deep well," from the engineers' point of view, means one which is sunk through the surface soil and the stratum below through which the water has been unable

to pass, and the deep well gets down to water below this stratum—water which has come from the higher ground where the soil, on which it lies, crops up on the surface. So water in what is called by the engineer a "deep well" is probably upland surface-water which has travelled through the soil. It is very pure, but hard, as we have learnt already. Water in wells that are merely deep in the ordinary sense may be pure if the well is a very deep one, and so made that no water from the upper part of the soil can flow in, but only that very low down, where it must have been filtered through a good deal of soil before it got into the well. But shallow wells are dangerous, because rain washes dirt and germs into them through the loose upper soil, and the soil may contain drains which leak, and manure from fields and stable yards may soak down and be carried into it. We must never drink shallow-well water unless it is boiled.

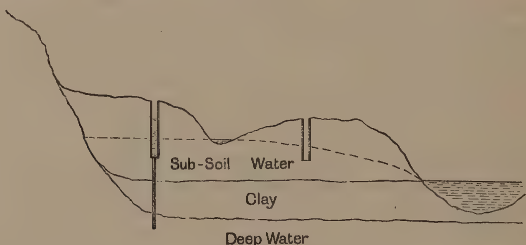


FIG. 80.—Deep and Shallow Wells.

Always under our feet there is, low down or near the surface, soil saturated with water, and that water is slowly moving on to the next stream or river, finding its way into the sea; it is carrying mineral salts with it, and the sun will take the water up again into the clouds, leaving the salts behind. This has been going on for untold ages of time, so it is no wonder if the sea is salt, for common salt is one of the salts which the water washes out of the soil. In some cases the sea has dried up and left nothing but salt behind. Some seas, like the Dead Sea, get so little water poured into them now, that they are slowly drying up and getting salter and salter, as the sun takes away the pure water it has distilled from them. The Dead Sea must have been much larger and deeper than it is now.

Hard water can be made soft in different ways. One mineral salt, carbonate of lime, is thrown down by the water being boiled, because the carbon dioxide is driven off which was in combination with it and held it in solution. When that happens, then the lime is thrown down and forms what we call the "fur" in boilers and kettles. After being

boiled the water is softer. This kind of hardness is called "temporary hardness," because it can be got rid of. Boiling does not get rid of the other mineral salt which makes water hard, sulphate of magnesium, and that is therefore known as "permanent hardness."

There are many ways in which water is softened, purified and made fit to drink, but the only one necessary for us here to think about is what we can do in our homes, and that we will leave for another lesson.

Blackboard Summary.

1. Water is absolutely necessary to life, and forms over two-thirds of the human body.

2. Water takes up more room when it freezes, and therefore may burst pipes in frosty weather if they are not protected, or if the water is not cut off or kept from freezing by being allowed to run.

3. Water freezes at 32° F. or 100° C°.

4. Water takes up bad smells and gases very easily, and therefore should be carefully protected.

5. A constant water supply is best; but if cisterns are used for storing water, they must be ventilated, have an overflow-pipe going through the wall and cut off short outside, and they must be provided with a cover.

6. Cisterns must be cleaned out from time to time and be in a place where they can be got at easily.

7. The most pleasant water to drink comes from deep springs and deep wells, but it is hard, and when used for washing wastes a large amount of soap.

8. Stored rain-water should not be drunk unless boiled, and shallow-well water is dangerous.

9. Water evaporates from outside traps and yard gullies in hot, dry weather, and clean water should be poured down them from time to time to fill the bend of the trap and so prevent air from the drain or sewer from passing out.

CHAPTER XXIX.

WATER—*continued.*

Necessary Apparatus.

A funnel.
Filter papers.
Powdered charcoal or fine earth.
Vessel for filtrate.
Salt water.
A little sand.
A very weak solution of Condy's fluid, or of permanganate of potash.
Two glass jars of water.

Accessory Apparatus.

A Berkefeld, or Pasteur-Chamberland filter.

A GLASS of clear, cold, sparkling water. What a delicious thing it is when we are thirsty! Have you ever considered why wells used to be looked upon as sacred and holy, and were dedicated to saints? Thousands of years ago sacred wells were known, and were put under the protection of some one or other of the gods worshipped by the people. It was because pure water was such a precious thing that men tried to make it safe in the best way they could, and they used to say that the gods would be angry if the water was made impure, and it grew to be looked upon as being under the protection of some special deity, and therefore sacred from pollution. Later on, when Christianity came, wells and springs were put under the protection of Christian saints. But sometimes those very wells did get polluted, and the people fell ill and did not know why. It is not so many years ago that no one knew that two diseases such as cholera and typhoid could be carried by impure water, and our knowledge of this fact saves thousands of lives to-day. The germ of cholera and the germ of typhoid can get into water into which any sewage is drained, and shallow wells and rivers are the two waters most likely to be affected.

Bad drains leaking into the soil may carry sewage from a house where someone is ill of typhoid, and that sewage may soak into a shallow well near by. One such well was responsible for a hundred cases in a little village of about three hundred inhabitants. For years

they had drunk the water and no illness had broken out because no disease germ had happened to get in. At the end of one November a person came to the neighbourhood who fell ill at once with typhoid. It was evident that he had brought the fever with him, for it takes about three weeks to develop, and he fell ill as soon as he came. All unknown to anyone, the drains of the house in which he was lying ill were leaking into the soil and running down hill close to the water-supply. Three weeks after his arrival, typhoid broke out in the village, though it was some considerable distance away. So about Christmas-time there was great sadness, for every house but one had the fever in it, and that one house was the school-house, which was shut up for the holidays. In one family five died. The doctors at once said, "Boil the water," for they felt sure it must have got infected somehow, but it took a long time before the disease was all stamped out, and when they examined the well and analysed the water they soon found out the truth. This shows us that we can never trust shallow-well water.

If water is not pure to begin with, it can nevertheless be made perfectly pure, clean, and safe by being filtered through great sand and gravel filter-beds. In our homes, however, when we are not sure that the water is pure, it is best to boil it. Filtration is necessary sometimes if it is full of visible dirt of any kind; but if we think that there may be dangerous germs in it, then the only safe plan is to boil it. People at one time used to trust a great deal to filters to keep them from evil germs in the water, till it was found out that the ordinary filters in use in private houses not only allowed germs to pass through, but, if carelessly looked after, grew germs themselves in vast quantities and made the water worse than it was before.

We can learn something about the effects of filtration by a very simple experiment. Here is a funnel which I will line with filter paper, and here is some water into which we will stir some charcoal or a little earth. Now we will pour the dirty water into the funnel and catch the filtrate in this clean dish as it slowly drips through. What happens? The dirt stays on the filter paper and the water that comes through is clean again.

We will try a second experiment. Here is some water in which salt has been dissolved; we will also stir in some fine sand and filter it through filter paper. What happens? The sand is left behind and the water looks quite nice and good to drink. Taste it. Is it good? No, it is very salt. What does this show us? It shows us that filters will remove things in suspension in the water but not things in solution.

Ordinary filters do not remove germs. There are, however, some which do. One is the Pasteur-Chamberland filter, and the other is the

Berkefeld filter. The first was invented by the great French scientist Pasteur, who wanted to be able to get water and other fluids free from germs without boiling them. His assistant, Chamberland, thought it would be a good plan to use the idea of this special filter on a bigger scale for filtering drinking water. The filter consists of a hollow candle made of fine unglazed porcelain-clay. The point of the candle, which is the nozzle, is downwards, and is the only opening it has. The candle

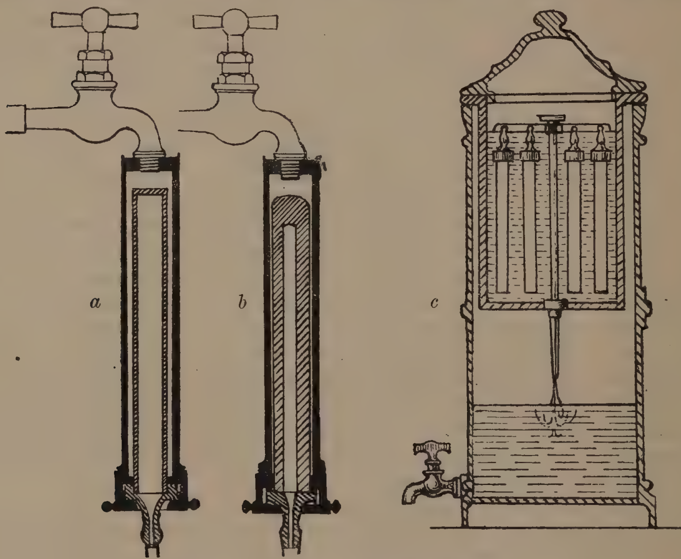


FIG. 81.—Pasteur-Chamberland Filter.

is then enclosed in a metal cover which fits it loosely and has a nozzle closed by a tap, and there is an opening at the top of the metal cover through which water enters from a pipe and fills up the space round the inner candle and is forced by the pressure of the water through the porcelain-clay. When the tap at the bottom is turned, the water comes out fresh and pure and free from germs.

What becomes of the germs which were in the water? They coat the outside of the candle and come to rest in the pores of the clay also. Any mud or other impurity also stays outside the candle, in between it and the metal cover. About every week the metal screws should be undone and the candle taken out and well scrubbed with a clean brush

kept for the purpose. If there is any danger of typhoid germs, the candle should be boiled to kill any germs which might be resting in the pores. If this is done, both with this filter or with the Berkefeld filter, there is no fear of typhoid germs. Nevertheless, if we have any reason to suspect the safety of the water which we drink, the wisest plan is always to boil it. Even the fine clay of the Pasteur filter will let some small, harmless water germs through after about the first twenty-four hours, and to be quite certain about not getting typhoid germs it would be wise to boil the candle every four or five days, as it is found that they can gradually grow through the pores; but as a rule the filter need only be cleaned once a week.

We can tell in a very simple way if water has much impurity in it by adding a little Condy's fluid to it, making it pink, or a weak solution of permanganate of potash. If the water is quite pure and good, the pink colour will remain; but if it is impure, then the pink colour will get paler and paler, turning yellowish, and perhaps fading quite away. Sometimes, when travellers are unable to boil or filter water, they test it in this way to see if what they are going to drink is pure or not, and they go on adding the permanganate until the pink stops fading. They know then that the oxygen in the permanganate of potash has oxidised the impurities of the water, and it is then possible to drink it. To drink pink water is not very pleasant, but it is better to do that than to get ill. It must not be thought, however, that this method gets rid of dangerous germs, but it does make the water less impure.

Here are two jars: one is full of water which I know to be pure and good; the other is water which I believe to be polluted by sewage. We will colour both to exactly the same colour with permanganate, and label the good one A, and the one which is suspicious B, and we will put them both away and look at them to-morrow. If we find that the colour of B is much yellower or paler than that of A, we shall know that B is not safe to drink without boiling.

There is a great deal more to learn about water. Chemistry and physics can teach us wonderful things which we cannot learn here, but we know enough to show us how important it is for any village, or town, or country to have a good water-supply, and to look after it properly. We know that people who put sewage and other dangerous things into the water may be responsible for the deaths of many people. We can think with gratitude of what a beautiful thing a clear stream, spring, or river of water is, and we can realise that, as no other drink can ever take the place of pure water, we owe a deep debt of gratitude to those who, years ago, taught us how to keep it pure.

Blackboard Summary.

1. Typhoid fever and cholera can be conveyed by water.
2. Shallow wells may be polluted by broken drains.
3. The safest plan with suspicious water is to boil it. To restore a fresh taste (lost by loss of oxygen) to it, stir it with a clean spoon, or pour it from one clean jug to another in pure air. Protect it from dust as you would protect milk.
4. Ordinary house-filters do not keep out germs.
5. Berkefeld and Pasteur-Chamberland filters keep out germs for a certain time, but should be cleaned every week, and if used with suspicious water the candle should be boiled every week, or, better still, every five days.
6. It is very important to have a good water-supply and to keep it pure.

CHAPTER XXX.

CLOTHING.

Necessary Apparatus.

A flat piece of marble or other stone.
Pieces of iron, wood, wool, flannel, cotton-wool, silk, etc.
Tripod.
Lamp.
Stem of a long clay-pipe.
A piece of wax taper.
A piece of iron rod. It must be of the same thickness as the clay rod.
Retort-stand or some other means of support for the rods.
Rod or stick on which to hang pieces of stuff.
Piece of flannel, and one of flannelette same size.
Reel of cotton.

Accessory Apparatus.

Microscope for examination of fibres of different materials.
Vessels and measuring glass for measuring the amount of water absorbed by various materials.
Equal-sized pieces of various materials.
Materials for demonstrating right and wrong methods of washing flannels.

All the lessons we have now had about the way in which the cells of the body work together for the common good have taught us many things; one of them is that if we do our duty, we shall help others to do the same, and that the citizen who is too lazy to work, and of whom no one can say a good word, injures others, and is not worth having. But besides this lesson, we have learnt others which should help us to live wisely and healthily.

Now, the great secret of health with regard to clothes is, that they must allow the skin to act freely, must keep the body at an even temperature, and must allow every part freedom to do its work.

I am sure you will all remember that we get the warmth of our bodies from the food we eat, and we remember that some foods were specially called "body-warmers." Food, as we know, is slowly oxidised—that is to say, it is burnt up in our bodies,—and the heat is regulated through the work of the skin. What is the ordinary temperature of the human body? Somewhere about 98° F., about half way

between 98° and 99° (98·4° F.). So wonderful is the regulating power of the skin, by means of the sweat-glands, that whether we try to go to the North Pole, or whether we live at the burning Equator, our blood keeps at about the same temperature, so long as we get proper food and clothing. But clothes do not warm us. It is not much good putting thick stockings upon ice-cold feet, unless we take exercise also; but when the feet are warm, the stockings will help to keep them so. If you wrapped this stone up in thick blankets and left it for days, you would find it and the blankets as cold as ever. But if you wrapped yourself up in a great many blankets, what would happen? You would get unbearably hot, and would soon throw the blankets off. They too would be warm. Where has that warmth come from? From the body. Yes, clothes do not warm us—*it is we who warm the clothes.* To a certain extent, clothes save food, for a person who wears very few clothes in cold weather needs to eat more food to burn in his body to keep it warm. But it is a mistake to wear a very large quantity of clothes, because they make the skin lazy, and the habit is weakening.

Here is a piece of marble, and here is an iron plate, and here a piece of wood, and here again are many different kinds of dress materials. All have been in this room for some time, and have all been exposed to the same temperature? Feel this piece of marble. Does it feel warm or cold? Cold. Feel this wood; does it feel warm or cold? It feels rather cold, but not so cold as the marble. Put your hand on this piece of calico and again on this soft, thick woollen stuff. Does one feel less cold than the other? Yes, the wool feels less cold. Now feel the marble and then the wool. There is a great deal of difference; the marble feels very cold after touching the wool. What is it that makes all these things feel so differently although they are exposed to the same temperature? Let us see if we can experiment in another way. Here is a piece of thin iron rod and here is a long pipeclay stem, which I broke off a churchwarden clay-pipe. Both rods are of the same thickness. I will light the spirit-lamp or burner and put it under this iron tripod, and support these rods in such a way that they only touch at one end of each, in a V shape, and that those two ends are both in the flame. The other two ends which are wide apart we will make rest at opposite ends of this piece of wax taper, which we have supported on the ring of this retort-stand and at the same level as the two rods (see fig. 82). Now let us see which bar gets heated first, the pipeclay one or the iron one. Which one do you think? Why, already the pipeclay end which is in the fire is beginning to glow red, but the iron is dark still. Now at last the iron is beginning to glow, but what else is happening? Look at the wax taper on which the two ends are resting. Do you see any change? Yes, the end on which the iron rod is resting is beginning to melt. Is

the other end melting? No, it is unchanged. Now comes a crash and the iron bar slips off the melted end of the taper and falls. We took care to put the whole arrangement where the red-hot end could do no harm if it did fall. We must pick it up carefully but not with our fingers. Now, very, very quickly touch the end which was *furthest* from the flame. Is it hot? Yes, very hot, hot enough to have melted the wax. Now touch the far end of the pipeclay. Is it hot? No, not at all. You can pick it up quite well at one end and hold it in your fingers while the other end is glowing red-hot. This teaches us that the heat began to travel along the iron bar very quickly, from particle to particle, by the power called "conduction." The iron conducted the heat away from the fire and led it to the wax taper. The pipeclay only conducted it away slowly. Iron, therefore, is a good conductor of heat, and pipeclay is a poor one. We can learn other lessons from these two things, but at present we want to think of what they can tell us about clothing. If you touch an iron bar, it leads or conducts away heat very quickly from your skin, and therefore the skin of your hand is chilled. If you touch a piece of iron in very frosty weather when the iron itself has been exposed to the cold, it may take away so much heat from your hand as to injure it severely. Labourers, sometimes, going out very early in the morning in a very bitter frost, have taken hold of an iron rake and had bad frost-bite from it. Touch this piece of wool again; it seems warm to your hand. Why? Because it is such a poor conductor of heat that the heat from your body cannot easily get away through it, just as the heat could not pass easily along the pipeclay rod.

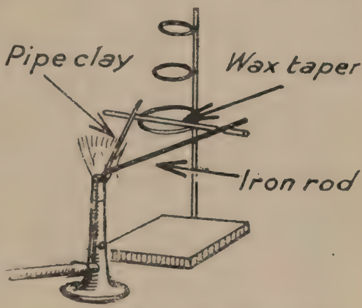


FIG. 82.—Experiment to show the relative conductivity of clay and iron.

In this country, we mostly want to *keep* our body heat, therefore we need to make our clothing of materials which are poor conductors. But we have to remember another thing, and that is, that if during exercise perspiration collects on the skin, it takes a lot of warmth to dry it off. That warmth has to be taken from the blood, which is therefore cooled. If a great deal collects and is dried off and no attempt is made to keep the body warm, it may become dangerously chilled. Chilled skin has less blood in it, and chilled blood has less power of defence, and germs may attack the delicate lining of throat and nose

and set up inflammation and "colds." Now, if we remember these things, we shall see at once that we need in our clothes, not only materials which, as a rule, should be poor conductors of heat so long as the weather is cool, but ones which if worn near the skin should have the power of taking up water, so that, if we are perspiring, the evaporation will take place from the material and not from the skin itself, which therefore avoids being chilled down. If we get very hot and perspire a great deal, it is wise to wear a material next the skin such as wool lightly woven, for the vapour (or steam as we wrongly call it) from the drying perspiration condenses on the wool, on its fibres and in its pores, and gives up heat again, and the wool is warmed and the body also. It is very bad to sit with wet shoes and stockings on and

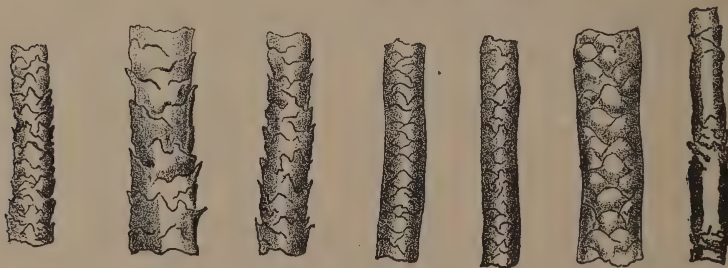


Fig. 83.—Wool Fibre.

let our feet get chilled. If we get our feet wet and cannot change at once, we must try to exercise and keep them warm, and then we shall take no harm. If our clothes get soaked through and we cannot change, we may get badly chilled, for water is a good conductor, and damp clothes conduct heat away very rapidly. If, however, we put a warm dry garment over our wet clothes and so prevent the water from evaporating, we shall probably escape a cold. A poultice is damp, but we cover it with dry flannel and it keeps us very warm. If we should be so unlucky as to fall into water and get wet through, and be so lucky as to get out again, then the best thing we can do until we can change is to put something warm over everything and walk home briskly. Wool is dearer than cotton, but it saves doctor's bills. It has to be carefully washed, otherwise it shrinks and gets hard. The fibre of wool has tiny scales, and if a quantity of wool is rubbed and beaten together, these scales catch in one another and form a thick feltwork. That is how felt is made. We can understand from this that if a washerwoman rubs a woollen garment together as she would rub a cotton one,

she quickly spoils it. Wool should neither be rubbed, nor wrung, nor boiled, nor put in very hot water, nor put in a hot sun to dry. If a woollen garment is greasy, soda helps to spoil it, and either borax or ammonia should be used. We can easily experiment with pieces of flannel and find all this out for ourselves.

Cotton comes from the cotton plant, which grows in India, America, and Egypt, and is sent in bales to England to be spun. The fibre has a peculiar twist in it, and therefore if we look at a few fibres of cotton-wool under the microscope we can recognise them from linen or silk. There is a modern method of preparing cotton for certain purposes, which gets rid of the twist and gives the fibre almost the gloss of silk (mercerised cotton). Cotton is a quicker conductor than wool, and, as ordinarily woven, does not absorb moisture well. Persons perspiring freely and wearing cotton, woven in the usual fashion, next their skin, are liable to chills if they sit in a draught or expose themselves to cold winds. A damp garment is a quick conductor of heat, and since little condensation takes place in cotton, it soon feels clammy, chilly, and unpleasant when soaked with perspiration. Its good qualities are that it is light, smooth, easily woven, cheap, and washes well. Flannelette is made entirely of cotton thickly woven, with the nap artificially raised and made woolly-looking. It is cheap and washes well, but unfortunately it catches fire very easily indeed, and has caused many terrible accidents. Some flannelette is treated with chemicals to make it catch fire less easily, but the effect of the chemicals is apt to wear off. Here, on this iron rod, I have hung two pieces of stuff of the same size and thickness. One is a piece of flannel and the other a piece of flannelette, and both have been carefully dried. I will hold the rod where no harm can be done, and put a lighted match under the flannel at the same time that someone else holds another under the flannelette. The flannelette is of a kind which has not been treated with chemicals as the "non-flam"

FIG. 84.—Cotton Fibre.

kind is. What happens? The flannelette burns up with a quick flare into a black, fluttering rag, and the flannel is only scorched. How easily a little child could be badly burned if it was wearing a flannelette dress or pinafore and got too near the fire, or if it began playing with a box of matches! There must always be a guard round the fire when little children are about, and matches are such dangerous things that wise parents keep them out of the way.

If cotton is very loosely woven, it will absorb as much moisture as a closely woven woollen material, but it has not the same power of giving up or keeping in warmth as wool, which is the best material for underclothes worn next the skin, especially for men engaged in heavy work. Iron-workers know that they must have good flannel for their shirts or else they are bound to suffer.

FIG. 85.—Linen Fibre.

Many kinds of stuffs are woven from cotton: besides calico, there are print, cretonne, fustian, velveteen, muslin, and many others.

Linen is made from the flax plant, which grows in Ireland, Russia, Holland, Italy, and other places. The stems are allowed to decay, and that gets rid of the soft parts and leaves the firm, useful fibres. Linen is made into cambric, lawn, linen-thread, table-linen, damask, and many other beautiful fabrics. The fibre is smooth and flat, which makes it feel deliciously smooth and cool to the skin. Linen has the advantage of taking a fine gloss, and so is used for shirt-fronts, collars, and cuffs. It wears well, but it is expensive, a very poor absorber of water and a very quick conductor of heat, which makes it a dangerous material for underclothing.

Silk is made by the silk-worm, and comes next to wool as healthy material for underclothes, as it is a slow conductor of heat and a fairly good absorber of moisture. It is soft and smooth, and very pleasant to the skin, and is much lighter than wool, but it is very expensive and requires great care in washing and in drying. It is easy now to buy cheap silk which is sometimes a mixture of real silk and imitation silk, and is sometimes loaded with tin. This kind of silk wears very badly.

Fur is very warm indeed; each hair of the fur is surrounded with air, and the whole forms a very slow conductor of heat. Waterproof

clothing, such as mackintoshes, goloshes, and patent-leather shoes, overheat the skin, as no perspiration can pass away, and the underclothes, stockings, and socks get damp and unpleasant.

It is very important to keep our clothes as fresh and clean as possible. When we think how much water is lost by the skin every day, and remember that it goes into the clothes, we realise how quickly these will begin to smell of stale perspiration, especially if they are made of cotton. We like to keep our skins clean and active by washing and rubbing, but we must see to it that the clothes we wear next the skin are clean also. When we take our clothes off at night we ought to give them a good shake to shake out scales of skin and any dust, and to allow fresh air to come in and purify them. It is not good to sleep in the clothes which we have worn all day. If we want extra warm things at night besides the ordinary nightdress, it is best to use a separate garment. Outside clothes should be regularly shaken out and brushed, if possible in the open air, and certainly not in the bedroom. You do not want the dust and germs in the house. In cold weather, arms and legs need to be well covered, especially for young children. Some people are very foolish about the way they will wrap up some parts very much and leave others very badly covered. It is a bad plan to wrap the throat up a great deal, as it makes it delicate; at the same time, it is also very foolish to leave the upper part of the chest hardly covered at all, for this is apt to lead to pneumonia and consumption. Clothes ought to cover the body evenly, and they should be light, fairly loose, and not interfere in any way with the work the muscles have to do, or with the ventilation of the skin. The skin feels a kind of suffocation if air cannot reach it and if perspiration cannot pass off freely, and this condition is not good for health. It is a mistake to wear a great number of clothes, for we weaken the power of the skin to act for itself, and make it more liable to chills. Some school-children wear an absurd amount of clothes, and others wear too little.

Fig. 86.—Silk Fibre.

All parents cannot afford to dress their children as they would like, and some have a very hard struggle to manage at all, but it would be a very

good thing if all school-children could have a uniform and simple set of clothes. This might consist of a warm woollen vest for girls, with serge knickerbockers fitted with washing linings, made separately and buttoned in. An elastic belt for the knickerbockers is a good plan, but it should be very narrow, little more than a narrow elastic run in, otherwise it will be very hot. It is a good plan to wear a good deep belt of double calico with shoulder-straps, and to this the stockings can be fastened by tapes and buttons, or by suspenders, and if desired the knickerbockers can be also fastened to it. This soft belt in no way cramps the body. Stays should never be worn by the growing child. Over the vest and calico belt there should come, in winter, a warm jersey, and in summer a

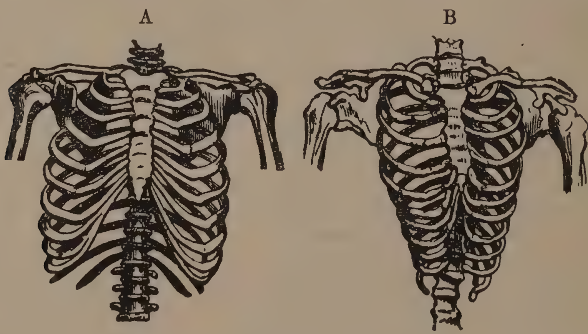


FIG. 87.

A, Bones of thorax (natural shape). B, Bones of thorax (distorted by tight-lacing).

cotton blouse, and over all a sleeveless frock with shoulder straps. Such a costume looks clean and smart, and is healthy and practical. Everyone who is clean and neat, well washed, well brushed and combed, feels the fresher and better for it; even horses work better for a good grooming. Very few people now are so foolish as to wear tight stays which cramp the lungs and stomach and give indigestion and other troubles. Many, however, still do not realise that their clothes are cramping them in other ways. Tight sleeves make it impossible to raise the arms above the head, tight waist-belts and tight garters hinder the circulation, injure the veins, and help to cause chilblains. Some people cramp the feet terribly. It may be that the boots are the wrong shape, but nevertheless the poor feet are thrust in and get their toes crumpled up. A foot ought to be a beautiful thing to look at, instead of which it is often very ugly indeed. Sometimes it is quite deformed, with toes doubled over each other, and with the painful hard lumps called corns which arise from the boot or shoe pressing on the skin and causing it to

harden until it presses down painfully on the nerve-ending in the true skin below. The big toe is also often pressed so much to one side by boots of the wrong shape that the joint becomes inflamed and enlarged and what is called a bunion is formed. Unfortunately, boots are expensive things to buy, and when people have not much money to spend it is difficult to get good ones, but we should try to get them to fit comfortably and not press our toes out of place (see fig. 88). Here is a picture of a foot as it ought to be, and another of one deformed by wearing ill-fitting boots. Boots for walking should have sensible low heels. It looks very bad to see someone on a country road or on dirty, muddy streets walking in French-heeled shoes. It is no uncommon sight to see a girl wearing shoes with high heels all worn down on one side and looking very slovenly indeed. Very high heels are not sensible for walking at any time, because they push the foot forward and therefore cramp the toes. They also injure the proper balance of the body and strain the foot, and are particularly out of place for rough wear and tear and real walking, and are positively dangerous, besides looking foolish. The well-dressed person is the *suitably* dressed person in all ranks of life. It is a reproach to English people that the girls of the poorer classes in many countries are better dressed than they, although the Continental girls often spend far less on their clothes. The reason is that they have very good taste, and do not believe in cheap imitations of expensive things, but like having their clothes well cut and well made, and therefore always look neat and trim. French women have learnt two of the secrets of good dressing: one is that a rich material badly cut and made in bad taste looks common and dowdy, while a simple material, if well cut and in simple good taste, can look very well indeed. And the other secret is that they dress suitably for the occasion, and that is a very important rule in good dressing.

FIG. 88.

a, Natural shape of foot. *b*, Foot distorted by ill-shaped boot.

It is a mistake to think that it is vanity to take pains with one's clothes, whether one is boy or girl, man or woman. We can certainly

think far too much about them and waste a lot of money over them. On the other hand, not to think wisely about them is to be slovenly and untidy. Everyone is right when choosing clothes to think about being suitably dressed, and then can forget about it and be at ease. Everyone is quite right to try and look his or her best. Girls are right to like neat clothes. If we see a girl wearing a nice dress and notice that her stocking has a hole in it and her shoe is all trodden down on one side, we often wonder if under the pretty dress her other clothes are clean and dainty, or whether it is a case of "all for show" on the outside. The girl who loves cheap, showy things is apt to choose materials which pretend to be what they are not, and soon look shabby and untidy. It is a pleasure to see nicely dressed people who respect themselves enough to take proper pride in good, well-made clothes and clean, healthy bodies. It is often a bad sign in people if they cease to care how they look; they soon lose their self-respect; and if we cease to respect ourselves, others soon cease to respect us.

Fig. 89.—Tracing from foot of boy of six years who had never been shod.

Blackboard Summary.

1. The body makes its own heat from the food eaten.
2. In this country we usually need to prevent the body heat from passing away quickly, therefore for our clothing we should use materials which are slow heat-conductors.
3. Slow conductors are wool, fur, silk; quick conductors are cotton and linen. Loosely knit cotton, on account of the air it contains, is a fairly slow conductor.
4. Flannelette is made entirely of cotton, and catches fire very easily.
5. Wet clothes should be changed as soon as possible, as they lead to colds, chills, and rheumatism.
6. Tight clothes and boots cramp and injure the body.
7. Well-cut, neat, clean clothes are a great mark of self-respect.
8. To be suitably dressed for the occasion is to be well dressed.

PART III.—THE HOUSE.

CHAPTER XXXI.

THE CHOICE OF A HOUSE: SOILS AND SITES.

Necessary Apparatus.

A lump of earth, well dried.
A tumbler full of water.
A glass jar three-quarters full of clay, well dried and rammed down.
A glass jar three-quarters full of gravel, ,, ,, ,,
A jug of water. A glass jar of clay and one of gravel, as above, but with a measured quantity of water poured into each the previous day.
A good type of brick.
A bad type of brick.
String.
A Salter's balance.
A shallow pan of water.
A fine glass capillary tube.
A saucer.
A few lumps of sugar.
A small piece of tinfoil.

Accessory Apparatus.

Specimens of bricks and stone.
Ventilating bricks.

Field Work.

Demonstration on houses.

We would all like to have our houses built in the best possible place, but many of us have to go on living in a house which is not quite what we would like, and some of us who may wish to go to a new house find it difficult to get what really suits us.

Nevertheless, if we are free to choose at all, we would like to know what is best. Here is a big lump of earth; it is quite dry, which is important. I am handling it gently, so that it may not crumble to pieces. I will drop it quietly into this glass of water, and we will observe it. Do you notice anything? Yes, quantities of air-bubbles

are coming up from it. Where was all that air and why is it coming off now? The air was in the spaces of the soil, between each little grain of earth, and is being driven off because the water is taking its place.

Sometimes this air gets shut up in the soil after a heavy shower of rain, because the water, caught and held in the earth above, shuts up the pores of the soil through which it could have got out. Sometimes it is driven along and comes up to the surface far away from where the rain fell, and as it travels along it may possibly get into badly built houses, and perhaps cause ill-health, especially if there should happen to be leaking pipes in the soil or decaying matter forming evil gases. This ground-air should never be allowed to come into houses, and it is quite easy to prevent it from doing so.

Some soils, such as a good depth of gravel soil, allow water to drain through quickly, and are warm. Clay soil is cold and damp. We can see this by a very simple experiment. Here are two glass jars, three-quarters full, one with clay and the other with gravel. We will pour the same amount of water into each jar. What happens? The water runs down very quickly through the gravel, but very slowly or not at all through the clay and remains in a pool on the top. Here are two other glass jars, treated in the same way yesterday. What has happened? The water in the jar of gravel has all collected at the bottom and if it could get out would run away. The top of the gravel is quite dry. Look at the clay. The clay is very damp for a long way down the sides, and the top still has some water lying on it. This shows us what a damp site clay soil is, and that if we have to build on it we ought to have the house built specially carefully so that damp cannot come in. If ground-water stands very high in the soil the house is likely to be very damp; but a house should never be built on a site that cannot be properly drained, nor should it be in a hollow at the bottom of a slope. Old chalk-pits are dry, for chalk lets water through very quickly. Damp soils are apt to cause rheumatism and colds, and they make people more liable to contract bronchitis and consumption. "Made soil" is often composed of various kinds of rubbish. Sometimes a hollow in the ground has been used for years as a place where the town or village throws its waste. All sorts of things may go there—ashes, rags, fishbones, decaying vegetable matter, and worse things than these, making a strange mixture which smells horribly. Later on, perhaps, when the hollow is filled up and has been left for some time, the ground is levelled and built upon. Underneath the houses are busy germs at work pulling all the rubbish to pieces and turning it into clean things for Nature's storehouse. But all that process takes time, and if houses are built on the top before it

is completed, then it is possible that unwholesome gases may be given off, and if the houses are not properly and carefully built, then these gases may get into them. This is especially likely to happen in the winter time when the houses are warmed by fires, for while warm air is rising up the chimney, cold air from soil and atmosphere presses in to take its place. The ground-air may also be driven upwards by rain at a distance, or change in the air-pressure may cause it to rise. In towns it often cannot escape through the asphalted pavements, and finds its way up under the houses, which thus, if they are carelessly built, act as chimneys for the soil. Such soil-air often predisposes people to ill-health. If it is absolutely necessary to build a house on such a site, then a layer of concrete should be put as a foundation, to prevent soil-air from getting in.

If a house is in the country, and especially if it is in a very exposed place, we often have to think about the wind, and choose a site where a hill or a belt of trees will protect it from whichever wind blows coldest and most often in winter. That wind will be a different one in different places. On the north-west coast of England people try and protect themselves from the south-westerly wind which blows very strongly during a great part of the year. In other places it is the bitter east wind that we have to think about; and in others, again, it is the north-east wind. But it is not good for any house to be too sheltered. A house needs plenty of air round it, and trees very near may cut off, not only too much air, but too much light, for, in this country, we have to think about getting enough sunshine. In the British Isles we get many cloudy days and many rainy ones, and we are grateful for the sunshine when it comes. In some foreign lands people have to protect their houses from too much sun, but here we have to think how much of it we can catch, and we must try to get a sunny house, one in which the rooms we shall use most shall get the largest share of sunshine. Sunshine is one of the finest tonics, and helps to make rosy cheeks, strong nerves, good spirits, and rich blood. Children need plenty of sunshine to make them rosy and well. The girl or boy, or for the matter of that, the grown person, who lives in one of the dark, dismal streets of a dismal town is probably very pale and pasty-faced. Even one day of sunshine in the country will make the blood of a pale, little town-bred child richer and redder. So we want to choose a sunny, cheerful house.

But we must not only think of whether the site is warm and dry and sunny and properly sheltered, we must also think of how the house is built. Here is a cheap, poor kind of brick, and here is a good, well-made, hard one. Both of them have been thoroughly dried. We will tie something round each of them, and weigh them both with this

Salter's balance, and write down the weights of each one. Now we will stand them both on end in this pan of water and leave them until the end of the lesson, and then weigh them both again. We will not keep them in this dry, warm room, for that would not be a fair test, but we will put them outside in a cool and perhaps a damp place. Bricks can draw up water out of a damp soil, and some bricks can hold as much as a pint.

Here is a very fine glass tube (capillary tube). I will dip it into this vessel of water. What happens? The water runs up the tube. I will lift it out. What happens? The water stays in the fine part of the tube, in spite of the fact that the other end of it is not stopped up by my finger or by anything else. It does not run out. Here are two lumps of sugar. I will put one of them into this saucer, which has a few drops of water in it. The other lump I will place on top of the first. What happens? The water runs up the lump and wets it all through, and runs up into the one above as well, and does not run out if I place it somewhere else. We see from this that water can run uphill if confined within a very narrow space. The particles of matter forming the sides of the space are stronger in attractive power than the particles of water. This does not, by any means, explain the whole matter, but it is enough for us to know that water will run upwards in very narrow tubes or spaces and be held there. Now, in the sugar there are plenty of narrow spaces. In soil, unless it is coarse, there are plenty also. Have you noticed on the seashore that when the tide goes down the pebbly beach soon dries, and, perhaps, the coarse sand gets very fairly dry quite soon, but the very fine sand may not dry at all, and if you try to walk on it your footprints fill with water. It is so full of fine spaces, "capillary spaces" as they are called, that the water cannot drain away. "Capillary" comes from the Latin word *capilla*, meaning a hair, for these spaces are often as fine as hairs. A brick may be full of capillary spaces and be placed on or against damp soil, and if so, soil-water will begin to rise up into it, and then into the brick above it, and so on to the rest, the damp always rising upwards. In vain in those cases do people light fires in the rooms and hope to dry the walls. They do certainly warm the air and make the room feel more comfortable and less damp for the time being, though of course the warmer air takes more water out of the damp walls and other water comes in from below to take its place. The damp feel of the room will return when the fire goes out, for, all unknown to themselves, these poor people are trying to dry the earth.

If a house is built badly and on damp soil in a damp climate where little evaporation can take place, the walls may hold an enormous

quantity of water. Such a house is damp, mildew grows on the paste of the wall-paper, the paper comes peeling off, and the people who live in the house suffer from coughs, colds, rheumatism, and the other troubles caused by damp.

It is quite easy to prevent ground-damp and ground-air from coming into our houses, and even if there are no cellars, every house should be free from both these dangers. Here again is the saucer and two fresh lumps of sugar. I will put the two lumps into the saucer, and in between the two I will put this bit of tinfoil, which must completely separate them. What happens? The water runs up into the first lump, but the top one remains quite dry. Why? Because the tinfoil did not let the water through. It was proof against damp. That is what builders do. Just above the level of the ground, after they have built the foundations of the walls, they lay instead of an ordinary row or course of bricks a course called a "damp-proof course." Then they go on building as before. This course may be of various materials, and is sometimes made of special bricks or of slates set in cement, but very often of asphalt materials sold in rolls on purpose for this. Or, cheaper still, coal-tar from neighbouring gas-works, mixed with sand to make it about as thick as mortar. It is spread evenly with a trowel over the width of the foundation wall to a thickness of three-quarters of an inch. On the top of the damp-proof course comes a good bed of mortar, and then the builder lays the bricks of the walls of the house itself. What he had been building before were the foundations, about which we must learn a little.

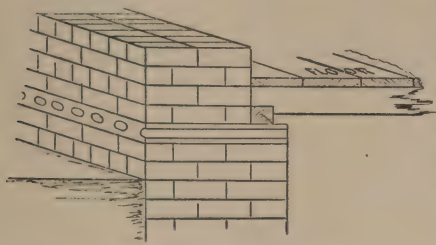


FIG. 90.—Damp-proof Course.

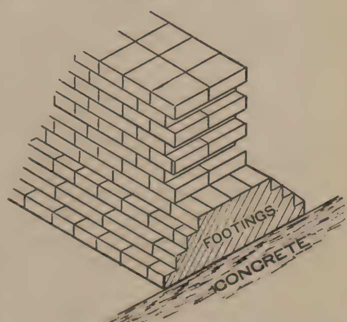


FIG. 91.—Foundations, showing Footings.

Foundations are very important, although, as they are out of sight, sufficient attention is often not paid to them. Unless the ground is very solid, it is necessary to lay a foundation of concrete under what

are called the footings of the wall (see fig. 91). Otherwise, if the soil is loose, the walls may sink after they are built, and crack in consequence. The bottom of every wall where it touches the ground must be at least twice, and better still three times, as broad as the wall itself. This makes it more difficult for the walls to sink or "settle" into the ground, for it distributes the weight over a larger surface. This wider part is known as the "footing." The widening is done by means of little steps or "offsets" if the wall is of brick, and by a slope if it is of stone.

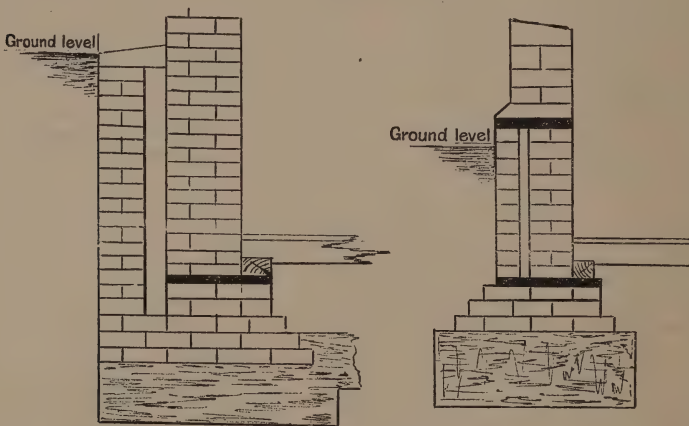


FIG. 92.—Foundations, showing Footings.

Both these figures show hollow walls. The air space is a preventive of cold and damp. The damp-proof courses are shown in black.

As soon as the foundations are made in the trench prepared for them, the damp-proof course is put in and the wall is begun. You will often look at houses now that you know this, and see if you can make out the damp-proof course. Sometimes people help to spoil the effect of such a course by allowing earth to accumulate against the walls above its level, sometimes by making flower-beds. Care should, however, be taken not to allow the soil to get above the course to any extent.

Another protection for a house without cellars is an air-space underneath the rooms of the ground-floor, making a sort of double floor. In the walls of this space there must be placed air-bricks, which are bricks pierced with holes to let air pass through. They are often not properly arranged, for there should be a current of air passing between the air-brick under one room and the air-brick under another. This space

serves two purposes. If the house is warmer inside than the outside air, the house air would rise upwards, as we know warm air does from being lighter. Cold air would press in from the ground-air. But if there are air-spaces and air-bricks under the floors, then it will get in more easily from them, and be pure and fresh. The circulation of air also prevents dry rot, which is a mould which attacks wood when there is not enough ventilation. We will look at some houses and find out where the air-bricks are. Sometimes people are not careful enough to keep the earth away from them if they are placed rather low down. We should try to see some new cottages being built by a careful builder, and that will help us to understand.

Now we will look at our two bricks and see if we can notice anything. Yes, the coarse, common, badly made brick reminds us of the lump of sugar, for the water has crept almost to the top. The other smooth, hard, well-fired brick has hardly absorbed any water. We will weigh them both, and see how much each has gained in weight. Since a brick can hold as much as a pint of water, we can easily judge how important it is to build houses with good bricks on the outside of the wall at least, as a protection against rain, even if, for the sake of economy, the inner bricks are not so good. We can realise, also, how very necessary it is to have a damp-proof course. No house can be considered really healthy without one, though many old houses have none at all, and may in consequence be very damp.

The house we would like to live in will be built facing south-east, or south-west, so as to get as much sun as possible; it will have plenty of window space, and every window will open at least half its area, and if we have sash windows, they will open top and bottom. We shall also try to have a house with fire-places in every room, for, even if we do not use the grate, a chimney is of great use and value in keeping the air of a room pure. Architects try to group chimneys in the centre of a building, so as not to lose their warmth, as is the case when they are built on the outside.

There are many interesting things to be learnt about healthy houses, and one of the best ways to learn, is to get someone who understands the subject to take us over a house which is being built and point out to us why each thing is being done in that particular way. Just such an apparently simple matter as laying the mortar between the bricks may make the wall dry or damp, according to the way in which the mortar is sloped off. If a house is built of stone, the stone ought to be laid in the same way of the grain as when it was found in its place in the quarry. If not, then the weather will make it crumble away too quickly. It is very interesting also to learn about the different kinds of wood. It is important that the wood used for build-

ing should be well seasoned; if not, it will crack and warp terribly, and every change of the weather will affect it. Window and door frames, cracked and warped, mean bad draughts and rain driving in during wet weather.

Another interesting thing is the reason why in this country we have sloped and high-pitched roofs, while in countries such as India, Egypt, and Syria there are flat roofs. We have to slope our roofs to make rain run off quickly. If we use good slates, we need not have a very steep roof, for rain will run easily and quickly off good slates without soaking in. If we use tiles, we shall need rather a steeper roof, for tiles absorb water more easily than slates do, therefore we must see that the rain runs off so quickly that it has no chance to soak in. If we use thatch, we must make a very steep roof. Thatching is not so much used as formerly, and in some ways it is a pity, for thatch keeps a house cool in summer and warm in winter, as it is a bad conductor of heat. Thatched roofs are much prettier to look at than slated ones. They are more trouble, however, to keep in order.

Blackboard Summary.

1. A house should be protected from ground-air and ground-damp.
2. All houses should have damp-proof courses and draw air from the atmosphere and not from the soil.
3. A dry, warm, gravel soil is best to build on. If a house is on clay, it should be very carefully built in order to keep out the damp which clay holds.
4. Made soils make bad building sites.
5. A house should be sheltered from cold winds, but not overshadowed by hills and trees so as to shut off air and light.
6. A house should get plenty of sunshine, especially in the rooms most used.
7. Bad bricks suck up much water.
8. A healthy house should have plenty of windows, and all should be made to open as widely as possible.
9. Sunshine, dryness, fresh air, and cleanliness make a house healthy.

CHAPTER XXXII.

THE DRAINAGE OF THE HOUSE.

Necessary Apparatus.

A piece of glass tubing, bent to form an S trap.
Water tinged with Condy's fluid or with red ink.
India-rubber tubing to fit on end of trap.
Small pair of bellows.
Instead of the rubber tubing and the bellows, use may be made of the rubber of the Bunsen burner, and the trap fixed on to its end in the place of the burner. Turn the gas on slowly at first and more strongly afterwards, to illustrate effects of gas pressure from drains or sewers on the contents of a trap.
House and school drainage systems to be used as illustrations, and pupils made to point out the uses and positions of traps and pipes.

Additional Work.

Inspection of drainage in course of instalment in new houses.

When we were learning about the body, we found out how certain citizens set themselves apart to get rid of waste matter. So it is in the house. Think of the house as a kind of larger body, and of the people in it as the citizen cells. On the care these cells take to purify and look after the house-body, depends its healthiness or unhealthiness.

Just as it is dangerous to keep rubbish in the body, so it is dangerous to keep rubbish cast off from the body in or near the house. The great thing is to get rid of rubbish of all kinds as soon as possible, or, if it cannot be got rid of at once, then to see that it does no harm.

We may happen to live in a house with a system of water drainage, a "water carriage system" as it is called; or we may live in a house or cottage in the country and have no drains at all, and although we ourselves here do not need to learn a great deal about drains, yet we ought to have some intelligent idea of how to look after them. There would be far fewer cases of drains going wrong and outbreaks of typhoid fever and diphtheria, if people knew a little better.

A house with a water carriage system has pipes running through it, whose upper ends are enlarged so that they may easily receive waste matters. For instance, we have a pipe fixed to carry dirty water away from the kitchen. The upper end of that pipe is really the sink.

There is perhaps a basin, fixed with a pipe to carry off the dirty water after we have washed our hands. That basin is the upper end of the pipe. There are also closet basins, which are the upper ends of pipes called "soil-pipes," which carry away impurities from the house as the sink and basin pipes do, and take them to the main drain or sewer. But perhaps it has at once struck us that we have heard of "sewer-air," and if we have pipes coming right up from the sewer and opening into our house, air from the sewer must be pouring into the house! Is not that very dangerous? Yes, it is very dangerous indeed, so dangerous that the law will not allow it to happen, and sanitary engineers have contrived ways to allow water to be poured down and yet to prevent air from coming up. It sounds very difficult, and yet it is a very simple thing. They said, "if we make a straight pipe, without ventilation, air is bound to come up; we will make a break in the pipe and a dip or trap to hold water shall be joined on to it, and the continuing pipe shall be cut off from the break by the water in the trap." So they made several kinds of traps; one was called the "D" trap because of its shape, but some people say that "D" ought to stand for Death, and that it is a regular death-trap, being very bad, and now the law condemns it (see fig. 93). Let us understand, first, why it was a trap, and prevented air from coming up, and why it was bad. It is a trap, first of all, because it *traps* the water. Looking at the diagram, we see that water enters from above at A, and flows out at B, where the pipe goes to join the sewer, but some always remains behind in a trap which is acting properly. Now let us suppose that bad air tries to come up from the main drain or sewer. It comes up, of course, in the contrary direction to the water, and, passing through B, gets into the trap C, but finds it cannot get into pipe A because the trap has enough water in it for the mouth of A to be under water. That is the idea of a trap, that it is a bend on a pipe to hold water. This D trap was bad for several reasons. One was that the pipe came into it at right angles and therefore splashed very much, and the water being full of filthy matter, the sides got plastered with dirt and the trap soon smelt very nasty. The right-angle at which the pipe came in caused the dirt to be deposited opposite its mouth, and it often accumulated so much that it choked up the mouth. The trap was made of

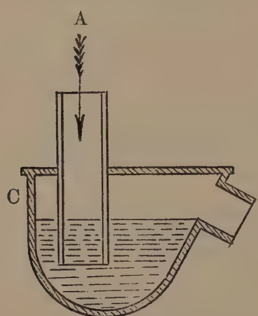


FIG. 93.—"D" Trap, so called from its shape. This trap has every fault.

lead, and acids in the splashed and accumulated dirt sometimes ate through the lead, and then all the parts round became in a horrible state. Another fault in the trap was that it had many edges in which dirt could and did stick, and the trap was one which did not clean itself. As a large surface of water is exposed in this trap, it evaporated

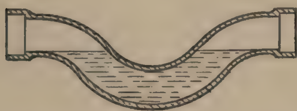


FIG. 94.—A poor trap. Water seal too shallow.

FIG. 95.—Trap as in fig. 94, but showing it open to drain air through the evaporation of a little water from the too shallow water seal.

very quickly, and there might not be enough water left to cover the end of the pipe, which only dipped down a little way into it. As soon as that happened, air could pass. Where such traps were used it was the case that the other arrangements connected with it were bad also; but we have learnt enough to see that a trap ought to be self-cleansing, that the water surface should be small so that there may be little evaporation, and that the sides should be smooth, so that nothing dirty can stick to them. Another important thing is that the part between the surface of the water and the dip, or else the end of the pipe, should be deep. This part is called the *water seal.* If it is shallow, a very little evaporation unseals the trap. Here in this drawing (fig. 94) is a picture of "a bend on a pipe to hold water," but as you can see in fig. 95, you need to empty it of very little water for air to be able to pass, and it is quite useless.

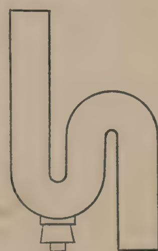


FIG. 96.—Siphon Trap.

Here (fig. 96) is the simplest modern form of trap. It is called an S or siphon trap. I have here a glass model of it without the screw opening at the bottom, and I will fill it with water coloured with a little Condy's fluid. Which part is the water seal? The part between the surface of the water and the top of the inner bend, and it ought to be at least $1\frac{1}{2}$ inches deep. We will empty some out. Is the trap unsealed? No, but the water seal is not so deep as it was. We will pour a little more out. Where is the top of the water? Just below the inner bend. The trap is now unsealed, air can pass through. I will empty the trap completely, and pour some more pink-coloured water steadily down. It flows away in a steady stream, but when I leave off

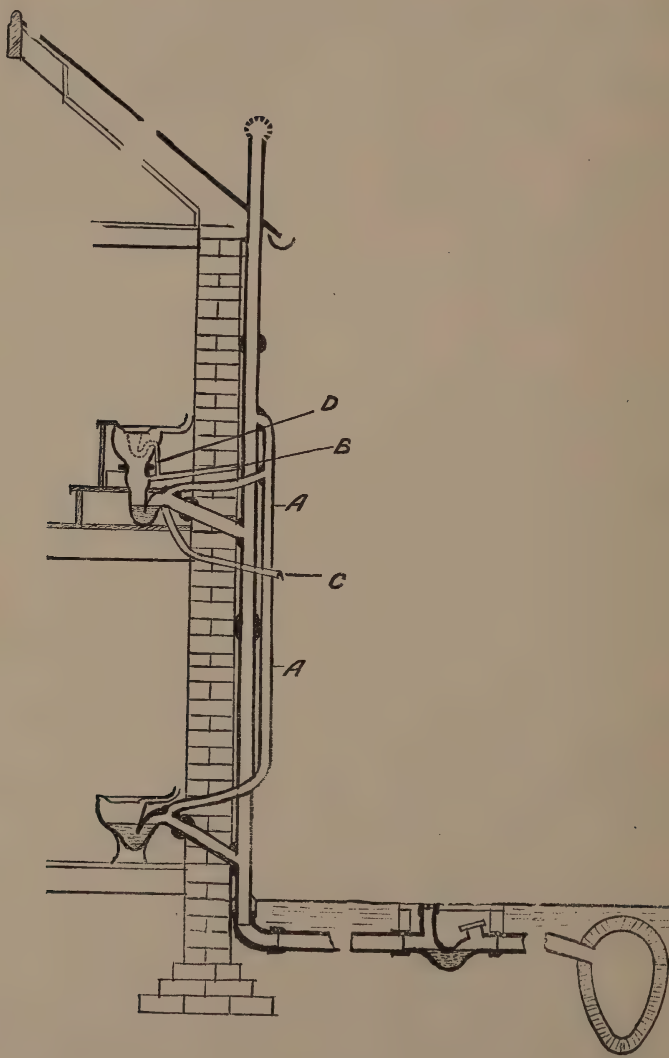


FIG. 97.

AA, Anti-siphonage pipe. B, Air-pipe from valve-box. C, Overflow from safe. D, Overflow from basin into air-pipe from valve-box.

pouring it down, the trap or bend remains full. Now I will pour it with great violence from a height. What happens? No water remains in the trap, it is unsealed. That shows us that even a good trap may become unsealed if a great force of water is plunged down into it. Now we will fill it again, and put a piece of rubber tubing over the lower end and fix into it the nozzle of this little pair of bellows, and blow gently. Let us imagine that the air from the bellows is bad air from the drain or sewer trying to force its way past the water. What happens? The water moves to and fro. We will blow harder. What happens? Bubbles of air manage to get through the water. We are blowing harder in proportion and making more air pressure than is likely to take place in the drain, but nevertheless we see the need for a good deep-water seal to resist possible pressure well.

A trap may also cease to act as a trap from water being siphoned or drawn out of it, and our lesson on air will have helped us to understand why. Let us imagine, as in the diagram, two closet basins on different floors, one directly above the other, and the pipes from both going through the wall to join the soil-pipe outside. Air is pressing on the surface of the water in each basin at the rate of fifteen pounds to the square inch, and is pressing on the other side of the water at the same rate, and in the soil-pipe as well. Now, imagine a pail of water emptied into the top basin rushing through the trap and getting into the soil-pipe, driving in front of it the air whose place it takes, and creating a partial vacuum behind it. As it passes the entrance of the next pipe leading from the lower closet basin, the air pressure behind the mass of descending water will be less than the air pressure on the surface of the water standing in the lower basin, and therefore this latter may be forced right out of the trap to join the other in the soil-pipe, leaving the trap completely unsealed. To prevent this from happening, a special entry for air is provided in such cases. An air-pipe, called an anti-siphonage pipe, is carried into the trap on the soil-pipe side, and this pipe runs up alongside the soil-pipe, until there is no other entering pipe to bring water into the latter, and therefore the air-pipe can now join the soil-pipe, and the soil-pipe itself be carried up above the eaves of the house and end in a wire cowl to prevent birds from building in it. It will now serve to ventilate the drains. We learn from this that, although traps are most useful, yet we must not put a blind faith in them, for we have seen that they may cease to act as traps if they are not looked after properly. On the other hand, if the plumbing of a house is taken care of, and if each person understands his or her share, there should be no trouble at all.

It is *not* enough to let dirty water discharge into the pipes. Everything thrown down a house-pipe should be followed up by a good

rush of clean water, so that all impurities are carried straight away from pipes and traps into the drains and sewer. It is very strange to find how careless people often are about this. Careless and ignorant people are great enemies to good sanitation. They throw all sorts of things down pipes, which of course choke up the traps. One of the worst things to throw down is hair, for it winds round joints and traps, and solid things stick in it; and fluffy, stringy, linty materials will also choke the traps. For that reason very old floor-cloths and dish-cloths often cause trouble, for little fluffy bits come off them.

We must not forget that a trap may cease to be a trap through the water *evaporating*. This is most likely to occur if a house is shut up, and it has frequently happened that people have gone away on a holiday, and come back splendidly well, but have fallen ill in a few days because they have come back to a house full of sewer gas. They have gone away and left the house empty and made no arrangements for getting the drains flushed from time to time, and therefore the water in the traps has dried up and the evil gas has come in. If no one is allowed in while the owners are away, then special care must be taken. Sometimes the traps can be plugged with plugs made for the purpose, or they can be stopped up with sand, which can easily be removed afterwards. Sometimes it suffices to fill the traps very carefully with water and then float a little oil on the top, which helps to prevent evaporation on the house side.

The traps of sinks often smell very offensively. They should be flushed thoroughly with hot water, followed by cold water, two or three times a day, and whenever water is poured down in which vegetables, such as cabbages and turnips, have been cooked, such water should always be followed *at once* by plenty of fresh, cold water. Pipes from kitchen sinks receive a great deal of grease, and this gets chilled as it passes into the pipes; it then clings to the side, and other matters stick to it. All this impure matter will putrefy and smell very unpleasantly. It is quite easy to prevent this state of things by pouring down hot water, and also, from time to time, using boiling water with plenty of washing soda in it, and following that up with hot water to carry the grease right away. Kitchen and pantry sinks should always be treated like this once a week. All house-pipes are the better for being flushed out occasionally with hot water and soda.

When using soda for a sink-pipe, in order to get rid of grease in the trap, we must warm the trap first by pouring in plain hot water. Sink-traps are particularly apt to smell unpleasantly for want of care. The trap for a sink is an S trap, and has a screw cap underneath which can be undone and the trap thoroughly cleaned out (see fig. 96). The pipe goes straight through the wall and ends in connection with a trap out-

side called a gully-trap. It is not allowable for the pipe to go straight down into the trap all in one piece, for the reason that it is desired to put as many difficulties as possible in the way of air from the drain getting into the house. If the water in the gully-trap dried up and the sink-trap were dry also, bad air could come in, but there is much less chance of it if the pipe is cut off at a certain distance above the trap, because then the bad air gets out into the open air and does much less harm.

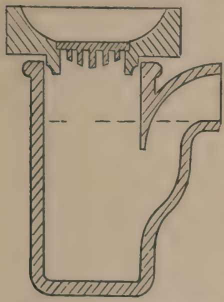


FIG. 98.—Ordinary Yard Gully.

These traps need thorough flushing and cleansing out from time to time. Rain-water pipes are also cut off above gully-traps, and so are all the waste-pipes from baths. We will look at some houses and find out these things for ourselves.

Sometimes in hot summer weather some of the gully-traps dry up, and therefore need to have water thrown down them to fill them up again. A house-drain going into the main sewer has a trap to cut it off from the sewer, and a manhole where the trap is made so that a man can get in and clean the trap if necessary. The manhole has to be tightly closed, as the drain runs open across it and other drains may join it there. The drains run across the manhole in open channels because it is at this part they are more likely to get stopped up than perhaps anywhere else, and if they are half open they can easily be cleansed. No bad air can get out of the manhole if the lid fits properly, but fresh air can get in from a ventilating pipe furnished with a grating with flaps which only open one way, and that is inwards. Fresh air can push these flaps open and get up the drain and up the soil-pipe and come out

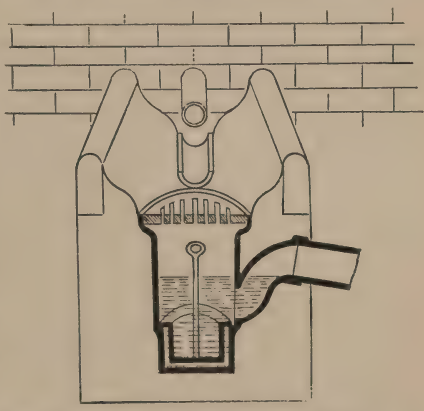


FIG. 99.—Sink Waste-pipe discharging over open channel leading to gully-trap 18 inches away, in compliance with the Model Byelaws. The trap is fitted with a bucket, which can be drawn up by a handle so that dirt and grease can easily be removed.

of the top part of the soil-pipe, the part which is called the ventilating pipe. By these means fresh air is always passing along the drains and soil-pipe of the house. Wherever a house-drain changes its direc-

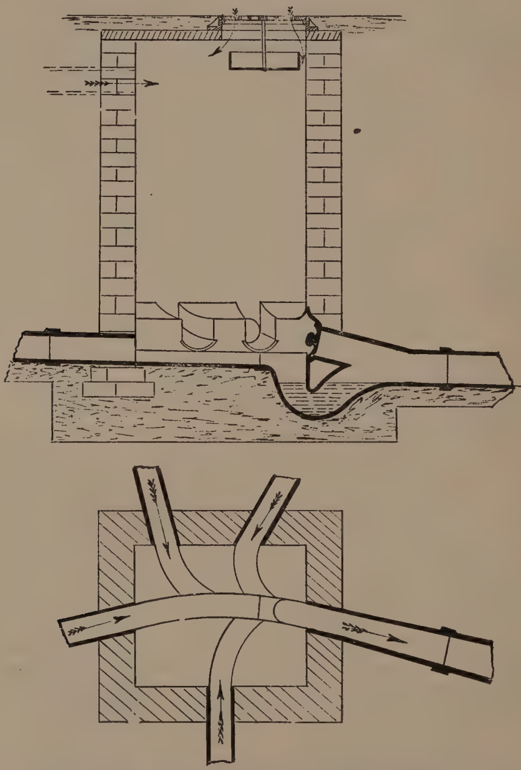


FIG. 100.—Elevation and plan of Manhole, showing open channel and the trap disconnecting house drain from sewer.

tion a little inspection chamber is placed, so that if any solid matter gets stuck at the curve of the pipe, it can be easily got at and washed away. These inspection chambers are like small manholes, but have no ventilation, and are tightly closed.

Another pipe needs to be mentioned, and that is the overflow pipe from a basin or bath. At the top of a lavatory basin, or at the top of a bath, we see an opening for water to flow through in case, by accident

or carelessness, they get overfull. Where does that pipe go to? It occasionally goes straight out of the house wall, where it is cut short, and the overflow easily noticed; but more often it joins the waste-pipe. It is very important to see that it joins it before the trap and not afterwards. If it joins it after the trap, then of course bad air can come up from the house-drain and come out from the opening of the overflow, and so be liable to be breathed in by anyone taking a bath or washing at the lavatory basin, to say nothing of its passage into the rest of the house.

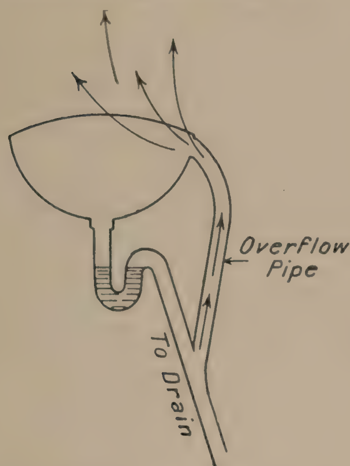


FIG. 101.—Lavatory Basin with overflow joining waste-pipe below the trap. Arrows indicate drain-air passing into house.

All traps, basins, lavatories, etc., should be kept as clean as possible, and be carefully treated, and then there will be no smell from them, and no fear of their being stopped up.

It is true wisdom to take care of all sanitary arrangements which are concerned in the clearing away of rubbish from a house. Sewer-air, as we have learnt, may have no smell. It does not in itself give any special disease, but if it gets into a house it may weaken people in such a way that germs can invade them. If a bad smell arises, it may of course be drains or sewer-air, but very often it is a dirty trap, dirty because dirty matters have been allowed to stay in it and breed germs. Never allow dirt to stay in a trap all night. The last water put into a trap should always be clean, especially when the trap will not be used again until the morning. It is wise from time to time to flush out basins and traps with disinfectant. Suitable ones are carbolic acid, in the strength of one part to twenty of water, or chloride of lime, one part to twelve of water. One of these can be put into the trap and allowed to stay there. But the simple

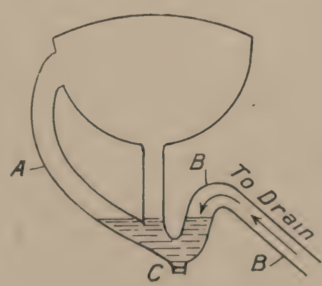


FIG. 101A.

A, Overflow pipe joining waste *above* the trap. B, Arrows showing drain-air prevented from entering the house. C, Screw cap for cleaning trap.

use of boiling water from time to time is one of the best possible plans, for it both helps to cleanse and to disinfect.

Blackboard Summary.

1. All waste matters must be got away from a house as quickly as possible.
2. House-pipes must be cut off from the house-drain by traps, and the house-drain must be cut off by a trap from the sewer.
3. Traps are bends on a pipe to hold water in order to prevent drain- and sewer-air from coming into a house. This they will do so long as they are well filled with water and the drains are properly ventilated.
4. Traps may cease to act from having dried up, or from having had the water forced out by air pressure and from other causes. They may smell badly also if dirty matter is left in them.
5. Traps will get stopped up if wrong things are sent down the drains.
6. Always leave clean water in a trap.

CHAPTER XXXIII.

THE CLEANSING OF THE HOUSE.

Note.—Every opportunity should be used for making this lesson as practical as possible.

It is desirable to recapitulate the lessons on the lungs and breathing. Experiments on potatoes with dust can again be carried out. Children can bring specimens of dust from their homes for culture, if desired.

A full account of the cleansing of a house can only be given in a Domestic Science course, therefore only general principles are described here. The teacher, however, if opportunity offers, can supplement with practical demonstration on how to clean various things, and how the use of dirty dusters and dirty water smears and does not cleanse properly. The customs, also, of the town, village, or school, good or bad, can be utilised as object-lessons, and the children asked to observe and give reasons for and against. These remarks refer also to the subsequent lesson.

We have seen how careful we must be to get waste waters and all sewage matters carried away by the drains, but we understand also that a house needs daily care to keep it fresh and clean in other ways. Perhaps some of us know the stuffy, sour, unpleasant smell of badly cared-for houses, and can contrast it with the freshness and sweetness of those which are properly looked after.

When we were learning how the different citizen cells looked after the welfare of the body, we learnt also that special care was taken to prevent dust from getting down into the lungs and irritating them. Not only does dust irritate the lungs, but it makes them less able to resist the germs which get in at the same time; as many of them cling round the particles of dust and are carried about with them.

Without dust there would be many fewer colds and coughs, much less bronchitis, inflammation of the lungs, and consumption. The air in a town, and especially in a manufacturing town, is full of dust. If we breathe it in, the citizen cells lining the air passages do their best to wave it back again, and if we are nose-breathers, germs and dust will be caught on the damp mucous membrane. But to live in a smoky town or to work in a coal-mine means that soot and coal-dust get into the lungs. This dust does not injure in the way that sharp stone-dust or metal-dust injures, nor does it do the harm which is done by soft, fluffy dust, such as comes from handling cotton goods and from flour-dust.

But no dust does good, therefore public authorities water the streets to lay the dust, and they make laws about work in factories where there may be particularly irritating dust, and they also make laws about certain dusty trades, and about the care of workers in mines.

We must all learn to breathe through our noses, and to breathe, even then, as little dust as possible. We must not keep dust in our houses. What is ordinary house-dust made of? If we can, we will look at some under the microscope. We shall find it to be a very strange mixture sometimes. A great London physician once collected some household dust from the top of a wardrobe in a lady's sickroom. More than half that dust he found to consist of organic matter, that is to say, matter that had formed part of plants or animals. He found scales of skin, bits of cotton, linen and wool, starch grains, bits of feathers, pollen dust from plants, and also mineral matters of various kinds. He made the remark that such dust would make excellent manure, but was scarcely a suitable thing to find in a lady's bedroom!

Each person in a house can help to make it worse or better, and from earliest childhood people should be trained to be orderly and clean in their habits, no matter how rich or how poor they may be.

With regard to all dirt in a house, the great point to remember is to remove it altogether, and not merely to move it from one place to another. Also there are always at least two ways of trying to clean—a right way and a wrong way; even in such a thing as scrubbing a floor.

Before scrubbing, sweep with a soft brush to get rid of the loose dust and dirt. Here is a rule for the scrubbing: *begin at the furthest corner of the room, and work towards the door.* Can any of you tell me why? If the worker has to go out and get fresh water, she will not have to walk over the freshly scrubbed part, nor, when she has finished, will she have to walk over the wet floor in order to leave the room. It is a good plan always to have a pad to kneel upon, for kneeling constantly on hard boards or stones is very bad for the knee-joint and is apt to cause inflammation. A little part of the floor should be washed at a time, using hot water, soap, and a scrubbing brush, and putting the weight of the body on to the brush. It is important also to scrub with, and not against, the grain of the wood. We should not use a great quantity of water and swill the floor, for that makes the boards unnecessarily damp, and the water soaking down between them finds dust and germs, and brings the germs enough moisture to enable them to grow on the dust. We should use sufficient water to clean thoroughly, taking care to change the water in the pail often; and after scrubbing each portion we must take a flannel and rinse off all the dirty water and soap; if we are scrubbing a table, we must also rub over with a flannel dipped in clean cold water and dry with a clean cloth. We

ought also to use a drying cloth for the floor. Sometimes we must sprinkle silver sand on the boards before using the scrubbing brush to get the wood clean, and if the boards are very dirty, we shall have to use soft soap. After the floors and tables have been scrubbed, the doors and windows should be left open to make a draught and help the wood to dry as soon as possible.

If we sweep a floor, whether of wood or stone, or if carpeted, we need to use our brains to do it properly. Some people will tell you to shut all the doors and windows before you begin. Others will say, "How foolish you are to shut all the doors and windows! Keep them open and let the dust go out by them." Suppose we try to use our brains before we decide the question. Are we going to sweep a room on the ground floor or on the upper floor? Has it windows raised above the floor or French windows level with it? *Which way is the wind?* Are we going to use something to lay the dust or not? But many people never think at all. Perhaps a girl is told to sweep and dust a room. In she goes with a long broom. The windows and doors are all shut, and she sets to work hard, and in a few minutes the air is full of dust. She collects some dust in a dust-pan, but a great part is flying about the room. Then she gets any kind of cloth, and begins to do what she calls "dusting." She flaps the dust from the piano on to the table, and from the table on to the chairs, and the dust from the chairs on to the floor from where it has just been raised, and then having very probably smashed some ornament, she looks round, bangs out of the room, and says she has "swept and dusted." So she has, but she has not *cleaned*; she has done little more than move the dust from one place to another!

If a high wind is blowing in through an open window, and it is nevertheless desirable to sweep in that direction for some good reason, then it is decidedly better to shut the window in order to prevent the wind from blowing the dust back into the room. But, as a rule, it is a good plan to have the windows open and the door shut. If we are giving a thorough sweeping it becomes necessary to take some of the furniture out, and to cover the remainder with light dusting-cloths to preserve it from the dust, of which, however, we ought to try and raise as little as possible. It is a good plan to use damp tea-leaves or bran to prevent dust from rising from a carpet, but, if we use tea-leaves, they should not be used just as they come from the pot, or they will stain the carpet. Put them into a sieve or colander, place them under the cold-water tap, and squeeze the water out well. Scatter the tea-leaves over the floor, and begin to sweep, holding the broom almost upright and using short strokes. Sweep *away* from you and *with* the pile of the carpet and, if possible, *towards* the fire-place, letting

each stroke of your broom overlap the last one a little. If you are sweeping out a corner, then sweep towards you. Damp tea-leaves hold the dust and prevent it from rising. When you have collected it, sweep it with a short brush into a dust-pan, and *burn* it in the kitchen fire. You burn many germs by doing that.

Sometimes we have to sweep the walls, and therefore the pictures have to be taken down. We must get a soft broom and tie a clean duster over its head. We must sweep down from ceiling to floor, letting each stroke of the brush overlap the last.

Now that we have swept walls and floor, we must get rid of the dust on the furniture and ledges. *Always dust the highest point first.* Use soft cloths, they catch and hold the dust, and remember to shake the duster frequently out of the window if there is no street below. Never flick the dust from one part to another, *gather* it up in the duster, and shake the duster over the fire or out of the window. With a soft duster, much dust gets caught in the fluffy material, but with a smooth cloth you cannot dust so well. Use clean dusters. Fold in the corners of your dusters, making a sort of pad. This prevents the breaking of small ornaments by the edges of the duster catching them and knocking them over. Use two dusters for furniture and paint. We often have to hold a polished piece of furniture in one hand while we dust it with the other. The hand that holds it leaves finger-marks unless it also holds a duster to grasp it with. Sometimes also a clean damp duster can be used by one hand while the other hand polishes the newly dampened place with a dry one immediately the first hand has done its work.

Brush the dust off upholstered furniture with a clothes brush, and pull the duster in and out through any open woodwork, such as ornamental backs of chairs and through the open parts of shelves, etc. When dusting tops of pictures, be careful to dust *behind* them as well, and when dusting tops and ledges of cupboards do not forget the tops of their open doors. Other dirt in a house, which has to be got rid of, is the rubbish from the kitchen. In country places, where people can keep pigs and chickens, odds and ends are not rubbish, for they come in very useful to feed the animals. In towns, however, it is a very different thing: scraps of fish, meat, and vegetables, potato peelings, egg-shells, and old tea-leaves rot and smell horribly if they are thrown into an ash-pit or a dust-bin. Flies lay their eggs in them, and swarm about them, and then come into the house; they crawl over the food, or drop into the milk, carrying dirty germs about with them on their legs and feet. All scraps of that kind should if possible be destroyed by putting them first into the warm ashes to dry, and then burning them in the kitchen fire.

The best thing for holding ashes, soot, and dry rubbish is a small dust-bin, either a tub lined with zinc, or a galvanised iron bin with a cover. (1) It should never be nearer to a house-wall than six feet. (2) It should not have to be emptied by being carried through the house. (3) It should be small, not more than six cubic feet in size, so that as it will have to be often emptied, owing to its smallness, it will not be possible to collect old rubbish. (4) Nothing but ashes and hard unburnable stuff should be put into it. (5) It should have a good cover to protect it from rain, as damp causes things to rot more quickly.

It is a very bad and unwholesome plan to have an old box or barrel close to the kitchen door and stuff it with a horrible mixture of ashes, cabbage leaves, bits of fish and meat, potato peel, dirty paper, tea-leaves, bones, etc. Probably, also, such a box or barrel has no cover, or if it has, the cover is never on. The mixture smells sour and disgusting, and swarms with flies and maggots in hot weather. People who keep dust-bins like that are a danger to themselves and to others. It is the duty of the councils to see that dust-bins are emptied properly. In country places, where it is not easy to empty dust-bins often, larger ash-pits are built, and have to be made according to certain rules, so that their walls cannot get soaked with evil-smelling, decaying matter, and so that fresh air can pass through and prevent evil gases from forming. These ash-pits must also be made in such a way that they can be cleansed easily.

Now we will put on the blackboard some of the things that we have learnt:—

Blackboard Summary.

1. A house is like a larger body, and if it is to be kept healthy it must also be kept fresh and clean.

2. Dust is harmful to the lungs and may contain the germs of different diseases.

3. In scrubbing a room, sweep the floor first to get rid of loose dirt. Scrub with plenty of soap and water, but do not swill the floor. Change the water often, and sweep towards the door.

4. In sweeping a carpet, sweep the way of the pile, use clean, washed tea-leaves, slightly damp, and collect dust and tea-leaves and burn.

5. In dusting a room, dust from the highest point downwards, that is, from walls, pictures, and cupboards first, and then the lower things. Use a soft duster, and get the dust out of the room as much as you can. Do not merely move it from place to place.

6. Burn all dirt and rubbish that is of no use to you or to your animals.

7. Do not put anything in the dust-bin that is likely to go bad and smell and breed flies, for they carry disease.

CHAPTER XXXIV.

THE CARE OF THE HOUSE.

Necessary Apparatus.

A sturdy, well-grown plant. A cellar-grown plant.

Note.—It is highly desirable that wherever possible the practical household work mentioned in the text shall be carried out by the children. Where this cannot be done, the teacher should demonstrate the practical work of cleaning as far as circumstances permit, and will therefore need to prepare the necessary apparatus before giving the lesson.

In these days it is very much the fashion to furnish a house on what is known as the hire-system. This is not a very good plan, for the payments have to go on a very long time, and it often tempts people to buy furniture which is much too showy and expensive. It is far better to begin with just a few things that are paid for, and then to buy others gradually. We should see that the furniture we get is well made and not "all for show." Sometimes foolish people buy furniture that looks very smart, but is so rickety that it comes to pieces very soon and never looks nice again. If our rooms are small, we should try to keep them as airy as possible by not having them crammed up with a great deal of furniture which leaves us no air space to speak of. The paper on the walls can be very cheap and yet very pretty and dainty. We do not want to choose ugly, glaring patterns, nor do we want to choose a dark paper because "it won't show the dirt." A dark paper absorbs so much light that in order to see well at night we are obliged to use much artificial light, and it does not look very bright or cheerful at any time. Healthy papers must have no arsenic in them, for the arsenic comes off in the form of dust and is very bad for us; they ought also to have smooth surfaces which will not catch and hold our enemies, dust and germs. Heavy flock-papers are very unwholesome, for they absorb the moisture from the breath and they catch and hold a great deal of dirt. It is quite easy to keep a smooth, light-coloured paper clean, if we take a little trouble, for when we clean the room we do it first of all in the way we have learnt, so as to raise

no dust, and also we can once a week tie a clean duster over a soft broom and gently dust down the walls. We want to have the window kept clean and bright, and made to open top and bottom, and we also want to make it look nice with pretty curtains and blinds. Sometimes people are so much "all for show" that they will make the window look nice, so that the neighbours as they pass think how nicely kept the house must be, and yet, if we go inside, we find the room behind the window very dirty and untidy. That is not true cleanliness. We should be careful not to darken our window too much, for in this country we do not get very much sunlight, and during most months of the year we want all we can get. There is an old saying, "sunshine drives out the doctor," so perhaps it is as well not to be too particular about our curtains and our carpets fading by keeping the life-giving sunshine out. It is often noticed that people who live in sunny rooms have much better health than people who live in dark ones. Children need plenty of sunshine, for it is a great tonic and makes red blood and rosy cheeks. That seems rather strange, does it not, when we remember that we live in the dark in a sense, since we are covered up with clothes, except for our hands and faces? But the truth is that the effect of sunshine is such that it pierces through our clothing, and also the light going in at the eye gets to the brain, which as we know controls the body. The result of this is a wonderful stimulating power, which quickens and enriches the circulation. The little red blood cells increase in number, the digestion is improved, and the blood gets more food to carry round and can do the work better. The citizen cells all over the body take in more fresh air and do their work more easily, and so every part of the body is better and stronger. It is quite wonderful what sunshine will do for the nerves, bracing them up and nourishing them. People who live in dark houses and slums are pale and pasty-faced, and very often children who have plenty of food but no sunshine do not seem half so sturdy, and rosy, and healthy as children who have much less to eat, but who get plenty of life-giving sunshine. Here is a little plant I grew from seed some weeks ago. It has been put in the sunshine and carefully watered. Look how splendidly strong it is and how bright and green! Here is another plant, also grown from seed at the same time, but when it was a few weeks old I placed it in a cellar that had hardly any light in it. What is the difference? *It is delicate and weedy looking and its leaves are a sickly yellow.* Plants can only grow green in the presence of sunlight, which gives them the power to manufacture the green colour. Human beings are very like plants, if you take sunshine away from them, they too lose their natural healthy colour, the roses fade out of their cheeks, and the healthy pink of the skin turns yellow or white. Many sick people crave

for sunshine, because they instinctively feel it will help them to get better, and it is noticed that people in hospital are apt to get well quicker on the sunny side. So we will try to get all the sunshine we can and be out as much as possible in the summer months, and store up the effect of sunshine in us against the many dark days of the winter.

Plants are very nice things to have in a house, for, as we know, they help to purify the air. It is not wise, however, to have heavy-smelling flowers in our bedrooms at night. Plants give out oxygen in the day-time and a little carbon dioxide at night, but not enough to make them unwholesome unless, as I have said, they have flowers which smell strongly. Pleasant as it is to see well cared-for plants in a room, it is not well to have kinds which are so delicate that we are afraid to have the windows open. There is a story told of how a plant became a wonderful missionary of health and happiness to a poor man and his wife. These two people were living in a wretched slum, and they were some of the untidiest and dirtiest people in the street. Once upon a time they had been proud of a pretty home and the woman was a clever housewife and kept the house clean and neat, but somehow or other she and her husband had become careless, she neglected the house, and he took to drink, and the children went about in rags. One day a lady, who knew them and who was very sorry for them, gave them a beautiful flowering plant to put in their window. She knew that Mrs Jenkins had lived in the country when she was a girl and that she was very fond of flowers, and she thought that perhaps the flower would make her remember happier days. Well, Mrs Jenkins put the flower in the window of the living-room, which had a deep window-seat, and she thanked the lady very much, and the lady said to her, "Be sure you give it plenty of sunshine and fresh air and clean water," and then she went away. Mrs Jenkins sat and looked at the lovely flower for a minute, and the tears came into her eyes as she remembered her old father's cottage in the country. Then, all of a sudden, she looked past the flower at the window, and it suddenly struck her that she had never seen such a grimy window in her life. She *did* feel ashamed to look at the clean, beautiful flower against the dirty glass, and she thought to herself, "Well, the sunshine can't get through all that dirt, I'll just clean the window." So she went and got a duster and she cleaned the frame and the ledges inside and out, and then she got a pail of water and an old leather and she washed every bit of the glass, taking care to go carefully into the corners. She had to change the water in the pail several times, because the window had been allowed to get so filthy. When she had got the dirt off and rubbed the wet off as well as she could, she polished the glass with a dry cloth till it shone. When she had finished her work she had the satisfaction of seeing the sunshine streaming on to the

plant, and she opened the window to give the flower some fresh air. Then she washed the doorstep to make it match the nice look of the window. When her husband came back for his tea he was very much surprised when he saw the white doorstep, the clean, shining, open window, and the pretty plant. "Well, mother," he said, "that does look better; but that paper, all peeling off, spoils the effect a bit and the paint looks very dirty, if you'll wash the paint, I'll paper the wall by the window." So next day Mrs Jenkins got some soft, warm water and dissolved a little soap in it, and used a piece of soft flannel dipped in the water. She was careful to keep changing the water and to use very little on the flannel, so that no dirty streaks could run down the paper or on to the floor. She didn't use soda, because that takes the paint off, and she only used a brush when she came to a very dirty place, because she knew that scrubbing is also apt to bring off the paint. Then she dried it all with a clean cloth, and it looked so nice that she felt she must try not to let it get so dirty again. When her husband came home he papered the wall by the window, but when he had done it he got discontented because the dirty torn paper in the rest of the room looked worse than ever; so he tore it all off and put on some new. There really was no end to the changes they had to make, for when Mrs Jenkins saw the neighbours stop to admire the lovely plant, she felt she must make a new, clean blind instead of the old, ragged one, and when the blind was up, she saw that the plant would look much nicer if there were pretty curtains, so she washed and hung some that had been lying by for a long time. Then her husband said that the carpet was a disgrace to the walls, and he began to save a little money by not going so often to the public-house, and one day he and his wife went and got a very nice carpet and a hearthrug. When these came Mrs Jenkins felt she must be more careful about the grate, so as not to scatter dust and ashes about the room, and that the floor must be scrubbed. So she scrubbed the floor in the way we have already learnt about, and when she did the grate she first rolled back the hearthrug and spread a piece of old newspaper over the carpet near the hearth, and then raked out the old ashes and cinders and took them into the yard and sifted them through the cinder-sifter, and found quite a lot of good cinders. Then she dusted the grate, and mixed the blacklead in a saucer with a little water, and spread it evenly and thinly over the ironwork, and then she said to herself, "Now I'll just show father what a grate can look like," and she brushed away so hard that in the evening her husband said he had never seen a better blacked grate! The steel fire-irons had got dreadfully rusty, and at first she tried a bit of fine emery paper, but she found they were too bad for that, so she got some fine bathbrick-dust and poured a little oil over it,

for she knew by experience that that was better than methylated spirits. Then she rubbed the mixture on with a bit of old flannel, and polished the steel up with a leather.

Mr Jenkins began to take a real pride in his wife's cleverness, and they both remembered the days when they were first married and had been so proud of their pretty clean home, before the man took to drink, and the woman grew slovenly and untidy, and ceased to do her hair properly, or began to go about in torn clothes, with her stockings in holes. By and by they saved up and bought some nice furniture, and Mrs Jenkins got so happy when she found her husband had stopped going to the public-house, that she grew quite pretty again, and she made up her mind never to be untidy or slovenly any more. In a year's time no one would have recognised the house, or the husband and wife either, for they had quite changed their old, bad habits, and had become very proud of their pretty, clean children and their comfortable home, and they often used to laugh and say that they owed the change to the silent lesson the beautiful flower had taught them.

Now we will put on the blackboard some of the things we have learnt :—

Blackboard Summary.

1. Sunshine in a house keeps the doctor out of it.
2. Clean, open windows make healthy homes.
3. *To clean a window.*—Dust the ledges, wash the glass with a wet leather, and polish with a dry, soft cloth.
4. *To wash paint.*—Use a flannel dipped in soap dissolved in warm, soft water. Dry with a clean cloth.
5. *To clean a grate.*—Roll back the hearthrug, remove the cinders and sift them outside. Blacklead the ironwork thinly, and polish briskly with a hard brush.
6. *To clean steel.*—Rub with emery paper, or bathbrick-dust and oil, using a soft flannel, and polishing with a leather.
7. *A clean doorstep is a good introduction.*

CHAPTER XXXV.

THE VENTILATION OF THE HOUSE.

Necessary Apparatus.

A glass tumbler.
Limewater.
Taper.
Matches.
Wide lamp-glass.
Soup-plate or dish.
Plasticine.
A piece of thin tin, or piece of smooth, non-porous cardboard.
Bell-jar or large glass cylinder.
Retort-stand with three rings, placed at varying heights—to be used with the tall glass cylinder. Otherwise use plasticine and bell-jar. The retort-stand and cylinder are preferable, but it may be found difficult to procure so large a cylinder.
Small blocks of wood.

We understand well by now how important air is to the body, for we have seen how it has to be carried to every separate cell, to keep it alive and help it to do its work properly. We have learnt that the life-giving part of air is the gas called oxygen, and that when we breathe pure air into our lungs the red blood cells take it up and carry it all over the body where the other cells can get at it and use it. We have learnt also that in using it they combine it with carbon and give out carbonic acid gas or, as it is also called, carbon dioxide. We know, moreover, that this last-named gas is harmful to the life of animals and human beings. We remember in our lessons on the blood and on the lungs, how the blood returning to the right side of the heart from all over the body is dark in colour, because it has then got much less oxygen in it and a great deal of carbon dioxide. We learnt that air with carbon dioxide in it obtained from breathing is very unwholesome, because such air contains gases from the body, animal matters from the skin, and moisture from the lungs, and that an unpleasant, stuffy smell soon arises from these waste, impure matters. When people are crowded together in a room into which no fresh air can come, the carbon dioxide gas increases rapidly at the expense of the oxygen, the waste impurities and the moisture also increase in proportion. The people present soon

begin to show signs of poisoning and partial suffocation: their cheeks flush, they feel dull, heavy, and stupid, and perhaps some of them cannot keep from yawning. In a badly ventilated railway carriage, containing many people, it is not uncommon to see the moisture from the lungs and skins of the travellers condensing on and running down the cold window panes. The same will take place in a room. If the people present have not been particular about washing their bodies and wearing clean clothes, the air will be much worse, and anyone entering into such a room or carriage from the fresh, pure air outside is liable to feel very sick from the smell of the sour, stuffy, unwholesome atmosphere.

People can die even in a room with an open window if there is not enough opening to clear away bad air and bring in pure. That was the case in the well-known story of the Black Hole of Calcutta, of which we have already heard. There a hundred and forty-six English prisoners were packed so closely together that none got enough air through the two small windows, and they were poisoned by the impurities arising from their own bodies during those awful hours. Only twenty-three ghastly pale and tottering people were alive next day and they were very ill for a long time with putrid fever and sickness, and several died.

Many people help to make their own health poor by breathing in stuffy air every day and night. This causes them to become pale and tired, and they are apt to get colds and coughs, and are very liable to fall into consumption and to contract other illnesses. How can it be otherwise? Every cell in the body is calling out for pure, fresh air and is asking to have the impure air removed, and yet the person is breathing in dirty air and starving his body cells. Remember, too, that the special cells in the blood which fight those germs that manage to get into the body can only do their work properly if they too have plenty of fresh air. If they are weakened and starved, the germs will easily get the upper hand. Germs causing colds and coughs are very common, and therefore we cannot avoid them, but we can strengthen ourselves against them by breathing in fresh pure air, and by getting it inside our houses as well as outside.

We have learnt how necessary it is to breathe through the nose, so that the air may get properly purified from germs and well warmed before it goes down into the lungs. But nose-breathing is good for another reason, for if we breathe through the nose, we can *smell* if the air is impure and dirty, and so take steps to purify it as soon as possible. When we are sure that a room is stuffy, let us try at once to open the windows wide, and let out the carbon dioxide gas for the plants to use, and let out also all the other impurities for the oxygen of the air to purify and sweeten.

Another thing we remember about breathed-out air is that it is warm, and that warm air is light and rises. So where should we have an opening if we wish to let out stuffy, breathed-out air? Near the top of the room. To let in fresh air it is best to open the window at the bottom, and to let out bad air we open it at the top. But a great deal depends upon *how* we open windows. Some people are terribly afraid of draughts and make themselves so tender that they catch cold at the slightest breath of air. Many people also do not realise that a thin, narrow draught is apt to do harm where a big one does none at all. Suppose we have a hot room and a big fire, and outside it is a cold, frosty day. What happens if the window is opened an inch or two at the bottom? The cold outside air is heavier and more condensed than the warm inner air which has expanded as it grew hotter, and directly the little slit of window is opened the cold air rushes in with great force and cuts like a knife. Perhaps it strikes just on a small part of the body of someone sitting in the room, and goes on striking just that one place, which in consequence becomes more and more chilled down. Such a draught *is* dangerous. It is bad to concentrate a narrow draught of cold air on one part of one's body. Powerful concentrated draughts raise dust and germs also. Do not be afraid of throwing the window open much wider and letting in a larger and less concentrated quantity of air, and, if your rooms are not full of dust and germs, you are not likely to catch cold from it. It is a very good plan to keep the window open a little at the top, even in cold weather, and as a regular habit. A current of air coming in high up gets warmed a little before it mixes with all the rest of the air, and the fire in the room keeps drawing the impure air up the chimney. A fire is a great purifier of a room. It is a mistake to say, as some people do, that they must let the fire out to purify the room. These people do not understand that a room warmed by a fire may be hot, but cannot, if it is clean, be as "stuffy" as a room without one. A fire in an open grate sends all the smoke and carbon dioxide it makes up the chimney, and hot air passes up with it, so that air from outside is always pressing in to take its place. If other air did not come in, then the fire would die out for want of oxygen. A room warmed by the bodies of human beings will be much worse as regards stuffiness if there is no fire in it. Lamps, candles, and gas all give out impurities, but gas-stoves are all right if they have proper draught and flues to carry off the bad air from them, but not otherwise. It is a very bad plan to shut up a room tightly and then light the gas to warm it, for gas and lamps use up a great deal of oxygen and make the air very impure if there is no proper ventilation. If we use them, we must always remember to allow more fresh air to come in, to make up for what they are spoiling. Electric light is the

healthiest of all lights, for it does no harm to the air at all, and does not injure plants.

Sometimes, in cold weather, it is a good thing to use the simple plan of lifting the bottom sash of a window and putting in a board which must just fit the vacant space. By that means an opening is left between the upper and the lower sash, and air from outside can find its way upwards and get in and mix with the warmer air near the top of the room before it touches the people present, therefore no draught is felt. This kind of ventilator is often called from its cheapness "the costless ventilator," or the "Hinckes-Bird" ventilator from the name of its inventor. It only acts really well when the outside air is travelling quickly, as happens on windy days, and for that reason it is particularly useful in stormy weather, when we want fresh air in our rooms but do not care about having the windows constantly wide open.

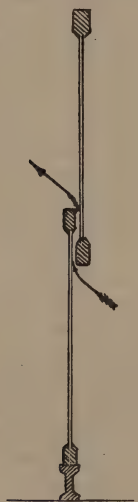


FIG. 102.—Hinckes-Bird Ventilator, shown in section.

Here I have a common glass tumbler, and I will pour a little limewater into it and shake it well. Does the limewater stay clear? Yes. What does that show? We remember that it shows that the air has not got in it much of the harmful carbon dioxide gas. Now I will dry the tumbler carefully and hold it upside down over this piece of lighted taper, which will now burn inside it. What happens? The flame begins to flicker and burns very badly, and at last goes out. Do you notice anything? Yes, the sides of the glass are smoky and there is a little water on them. Now we will quickly pour a few drops of limewater into the glass and shake it up as before. What happens? The limewater has turned milky, and little bits of black are floating about in it. Do any of you remember from our other lessons what it is that makes the limewater turn milky? Carbon dioxide gas. Yes. What does this experiment show us, then? That the air which was clean and pure before the candle was burnt in it, became dirty and contained carbon dioxide afterwards What is the "wax" of the candle made of? I will tell you. It is made of carbon, hydrogen, and nitrogen. The reason why the candle wastes away is because oxygen is joining on, or *uniting*, as we say, with the carbon of the wax as the candle burns. If the candle gets plenty of oxygen, it oxidises the carbon well and sends it off in the form of carbon dioxide. If it does not get enough oxygen, the carbon cannot all get oxidised and is thrown off not fully burnt and in the form of black smoke. This is, of course,

a waste of the carbon, as it has not been made to yield up all the light and heat it is capable of giving if it is properly oxidised. The burning of a candle and the reason for the different colours in a candle-flame depends upon the supply of oxygen to burn up the carbon and hydrogen of the wax. We noticed some drops of water on the glass inside. Where did these come from? They came from the union of the oxygen of the air with the hydrogen of the candle, for water is made up of two parts of hydrogen to one of oxygen (H_2O).

Why did the candle go out? The whole bottom of the glass was open for air to get in, was it not? Let us make another experiment and see if we can find out the reason why a taper or a candle will burn well in the open air and goes out when held under the glass.

Here we have a big lamp-glass such as is used for a Duplex lamp or a large circular wick. Here too is a soup-plate with some water in it. In the middle of the water we will fix a little island of clay or plasticine, and on the top of it we will put a little bit of wax taper and light it. Now we will lower the glass till it is standing in the water. The conditions are just the opposite of what they were just now, when we held the taper inside a tumbler. Then the tumbler, which can be thought of as representing a room, with the taper representing a person breathing in it, was open at the bottom for air, and yet the taper died out. Let us now see if the light will live if the glass is closed in at the bottom and open at the top. Watch the flame! What is happening? The flame burns brightly at first, then it gets weaker and weaker, and perhaps lingers on, very small and poor, or perhaps goes out altogether. Now we know from our experiment with the limewater that the air became very impure in the tumbler, and both experiments show us that something is seriously wrong in spite of our having had openings for fresh air. The light dies out just as the people died in the Black Hole of Calcutta, in spite of the open windows in the room.

Now we will lift the lamp-glass a little and light the taper again, if it has gone out, but perhaps ours has not quite gone out. What happens? If our taper is still burning faintly, then, the moment we lift the glass a little from the water, the flame begins to burn quite brightly and well. Let us see if we can find out the direction in which the air is moving. Here is a tiny shred of fluff on the end of this needle. We will hold it close to the bottom of the lamp-glass. What happens? The little bit of fluff flew off the needle and got into the glass. What does that show? It shows that air was rushing into the glass. Now let us hold a similar piece over the top of the glass. It is carried right off the point of the needle and into the air, away from the glass. What does that show? That air is coming upwards out of the glass. Is that air pure? What was the air like

which we found collected at the top of the tumbler? Impure. Yes, here the air can get out, but we know it must be just as impure as the other. So these experiments show us that, if lights or people are burning or breathing in a room, they are likely to suffer unless there is proper ventilation, and that if we make a place for bad air to get out, it is not much use unless we have an opening for pure air to get in. We must therefore have both: an inlet for pure air, and an outlet for the impure air. In a room with a chimney and an open window we have both, especially if we have a fire in the grate, for the fire draws in the fresh air from the cracks and crevices round the doors and windows, and carries bad, hot air up the chimney. So we see how mistaken a thing it is to say that letting out a fire purifies the air of a room, and we also see what a mistake it is to stop up a chimney. Some housewives cannot bear to leave a chimney open if there is no fire in the grate. They are afraid of rain or soot coming down and spoiling the appearance of the grate or the fire-grate ornament. But it is quite easy to manage, for we can easily have a pretty screen standing in front, and so leave the chimney open.

We can make another experiment with a lamp-glass, or a bell-jar, or a wide glass cylinder, open at both ends. We will allow plenty of fresh air to come in at the bottom, as before, but we will cover the top with a piece of tin, in which we have pierced only a small hole, and we will hold the tin down firmly, so that air cannot get in round the edge. What happens? If the hole is very small the taper goes out. Why? Because the bad air could not get out fast enough. That teaches us that we must allow a proper-sized opening for each person or lamp in the room, both for air to come in and for air to pass out. Forty-eight square inches are allowed for each person, for it is found by experiment that in ordinary cases that space is enough to supply each person with sufficient air. But theory and practice are different things, and we find that much depends on the way of the wind, its strength, the difference in temperature between the room air and the outside air, and whether the opening has smooth or rough sides. From all these considerations it results that the common-sense plan is to accustom ourselves to live in rooms with open windows, and every now and then to give them an extra good airing. We have to remember that a man in twenty minutes makes too impure for perfect health the whole air of a room containing 1000 cubic feet of air-space, that is to say, a space measuring 10 feet high, 10 wide, and 10 long. If two people are in such a room, then they spoil the air at the end of ten minutes. We see therefore that every man requires to be supplied with 1000 cubic feet of air every twenty minutes. Why does he need that? Do you remember how many parts of carbon dioxide gas there are in

10,000 parts of air? Yes, 4. Then in 1000 parts there would be ten times less, since 1000 is ten times less than 10,000. So we would have only $\frac{4}{10}$, or, to put it in decimals, 0·4 of carbon dioxide. Now supposing we had a space of 1000 cubic *inches*, we know that 0·4 of that would be carbon dioxide, that is to say, that space would hold, not a whole cubic inch of the gas, but only 0·4, less than half. If we had a space of 1000 cubic feet, the proportion would be just the same, and we should have 0·4 of a cubic foot present. Now it is discovered that if carbon dioxide is breathed out by the lungs of men and animals, it is never found alone as it is when a chemist puts pure carbon dioxide into anything. No; it is always accompanied by impure waste matter and by water from the skin and breath. These are the things which make a room smell stuffy and sickly. It is they which do most harm, but it is not easy to measure them. Nevertheless, we know that if in a room containing only 0·4 of a foot of carbon dioxide to every 1000 cubic feet of space, 0·2 of a cubic foot is added to every 1000 out of someone's lungs, making 0·6 in every 1000 cubic feet, then the room begins to get unwholesome. Now it happens that a man gives out about 0·2 of a cubic foot every twenty minutes, and therefore it is quite easy to see that he ought to have a fresh 1000 cubic feet every twenty minutes, which means 3000 cubic feet an hour.[1] In this country it is difficult, with ordinary ventilation, in winter, to change air more often than three times an hour without an unpleasant chill and draught; so we try to give every person 1000 cubic feet to start with, and with an opening for fresh air to come in of 24 square inches, and for bad air to go out of another 24 square inches, making 48 square inches in all, we find that 3000 cubic feet of air can pass in and out per hour. If two people were in a space of only 1000 cubic feet, the air would have to be changed six times, of course. We ought not to have more carbon dioxide than 0·6 of a cubic foot present in every 1000 cubic feet of air, if the extra 0·2 has been made by the breath of human beings or animals, but unfortunately we find a great deal more than that in stuffy rooms, and such air is very unwholesome indeed. In many schools and public buildings we have artificial ventilation, and by warming the air it can be changed much more often than three times in an hour without making a draught. The manager of a very large boot factory not long ago said that since a good system of artificial ventilation had been put in, there had been a great difference in the health of the workpeople, which had improved very much indeed. Formerly a good deal of illness had been caused by such things as colds, coughs, and influenza, but now they were very rare. With plenty of fresh air passing through a room, germs and unwhole-

[1] See Appendix for further details concerning problems of ventilation.

some air are carried away very quickly before they have time to harm us. Very dry, hot air is not good for us to breathe, and that is why in artificial ventilation we take great care to see that there is plenty of moisture in the air, and also why, if we use stoves and radiators, we set dishes of water on them; for if the air does not hold all the water it easily could hold at the degree of warmth it has reached, it will rob it from everything it can. Therefore air which is too dry takes moisture from the skins of people present and from the inside of their noses and throats, and dries them up too much, and often the quick evaporation of water from the skin in what is really quite a warm room makes people feel almost chilly. In some cases where sufficient attention has not been paid to this, people are apt to suffer from a kind of throat irritation, because the mucous membrane becomes too dry.

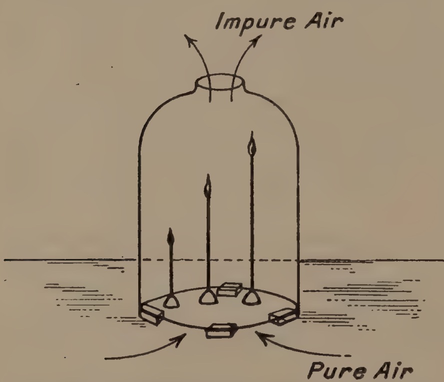


FIG. 103.—Taper burning under bell-jar raised on blocks.

Now we will make another experiment. Here I have a large bell-jar or open glass cylinder, and on this stand I have fixed, with the help of a little plasticine, three pieces of taper. We can if we like use a retort-stand and fix the tapers (or candle ends) on rings one above the other. If we use plasticine and a bell-jar, we must see that one taper is very short, only about an inch long. The second taper may be about four, and the third taper about six to seven inches in height. We will fix them as far apart as the width of the bell-jar will allow us. Now we will put little blocks of wood, or even little lumps of plasticine, under the edge of the bell-jar, in such a way as to raise it all round at least a quarter of an inch from the table. Now we will take out the stopper of the bell-jar and put the jar itself on one side ready. Next we will light the tapers and put the bell-jar over them with its edge raised in the way we have seen (fig. 103). What happens? The tapers all burn well and brightly. Why? Because they are getting plenty of fresh air at the bottom of the jar, and because the bad air is able to escape at the top. Now we will quickly pull away the bits of wood or the plasticine, and equally quickly put the stopper into the jar. What

happens? The top taper has gone out. Now the second taper is dying too, and the third burns a little longer but at last goes out also. Why did this happen? The tapers went out because they had used up the oxygen and made too much carbon dioxide. There was no fresh air coming in to give them more oxygen, and no outlet to take off the bad air. But why did the top one die off first? Because it was getting the hot, bad air from the two below it, for hot air is light and rises as we have already learnt. The second taper got the bad air from only one below, and it managed to last a little longer, and the third one lived longest of all, because the air down there was freshest. If you have been in a room with gas lit and several people in it, and have had to get up a ladder, to hang up a picture perhaps, you may have been surprised, as you got up high, at the heat of the air and the strong smell of gas. All these experiments show us very clearly that, in ventilating our rooms, we need to have an opening somewhere near the top, for warm impure air to go out, and an opening lower down for purer and heavier air to come in. We should not have the inlet ventilator too close to the ceiling, because, if we do, the air coming in is apt to strike against it and fall down lower at once before it has had time to get warmed up a little. Being cold, it therefore strikes unpleasantly against the people in the room. We want it to travel slowly along and get slightly warmed first. On the other hand, if we have the openings too low down, a whole quantity of air is apt to be left alone to stagnate at the top of the room, rather like a lake of dirty air upside down over our heads.

Let us then try to accustom ourselves to appreciate fresh, pure air, and to see that we get it in our houses, both by day and night. Let us remember to get into the habit of being nose-breathers and not mouth-breathers, and let us, when we are in the open air, remember several times a day to take a few very deep breaths. In our houses let us recollect that gas and lamps and candles all use up air, just as human beings do, and that all give out impurities. Let us see to it that we have open chimneys in our rooms, and let us accustom ourselves to open windows and, in any case, to give our rooms a thorough sweep out with fresh air every now and then during the day. For fresh air, cleanliness and sunshine in the house mean rosy cheeks, bright eyes, and healthy appetites.

Blackboard Summary.

1. Body and mind will both suffer without fresh air.

2. People shut up without fresh air will die; if some air gets in, although not enough, they will not die, but will feel tired and ill, and perhaps be seriously ill afterwards.

3. People who spend many hours daily and nightly in stuffy air are apt to be pasty-faced and suffer from bad health. They easily catch cold, and are liable to many diseases, especially consumption.

4. To keep the air of a room fresh and pure there should be an opening near the top for impure air to go out by, and one lower down for pure air to come in. A window open top and bottom does this. In our country every room ought to have a chimney.

5. We ought to flush rooms out with fresh air and not be afraid of open windows.

CHAPTER XXXVI.

VENTILATION (*continued*).

We have seen something of the way by which we succeed in keeping our rooms fresh and sweet. We understand that we must no more breathe stagnant air than drink stagnant water. Air, as we know, is made up of a mixture of several gases, and we talk about the *diffusion of gases*, meaning by that term the power which different gases have of mixing with each other. Diffusion is very slow, so slow that although it is true that air can get into a room through a brick wall if the wall is dry, owing to the power of diffusion, yet such a fact is of no practical value in ventilation. We have learnt that a fire in a room helps ventilation, but perhaps we do not yet understand why it is that an open chimney, even if there be no fire in the grate, is such a help. It is because if wind blows across the mouth of the chimney it causes an upward current at right angles to itself. Therefore air is drawn up out of the room below, and fresh air has to come in through doors, windows, and crevices to take its place.

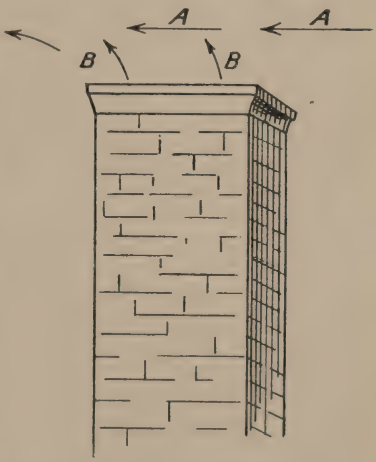


FIG. 104.—Wind blowing across a chimney and aspirating air from it. A, Direction of wind. B, Air drawn from chimney in same direction.

There are two kinds of ventilation: (1) natural, and (2) artificial. Natural ventilation is the one we have been talking about, for, although a fire-place is perhaps hardly "natural ventilation," yet it is so usual and so well known that we can consider it as such. The other things used in natural ventilation are open windows, doors, and ventilators, all

of which are openings to the outside air, and their action depends on the natural movements of that air. We can use the chimney not only to draw air out from the room at a low level, but we can also use it to draw out the hot, stale air which has moved to the top. We can do this by putting some kind of ventilator in the chimney-breast high up near the ceiling. Such a ventilator must be provided with hinged flaps which can only move *inwards* towards the chimney. When the air of the room presses against these flaps, they open, and the bad air passes in and joins the smoky or other air inside, and so passes into the outer air at the mouth of the chimney. If, on the other hand, air in the chimney presses against the ventilator, it merely shuts the flaps more firmly against the framework, and smoky air cannot get out into the room.[1]

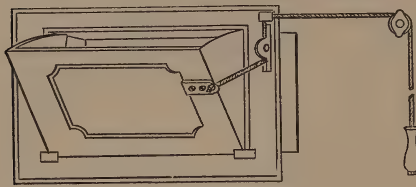


FIG. 105.—Sheringham Valve.

We have already learnt about the "costless ventilator," made by raising the lower half of a sash window and putting in a board to fit the space, by which means air passes into the room just where the upper and lower sashes overlap. A very usual form of ventilator is an iron box fixed in the wall above the heads of the people. The side of this box next the open air is made, not of solid iron, but of grating, so that air can pass through freely. The side which is next the room is movable, forming a valve, and can be opened and shut by a long handle. As it opens it slopes forward from the top, so that air passes into the room in an upward direction and becomes more or less warmed before it moves downwards to be breathed in by the dwellers in the room. Such a ventilator is known as a Sheringham Valve.

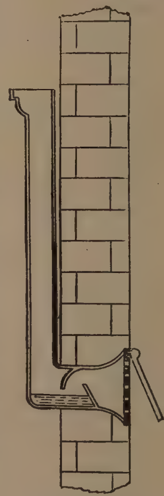


FIG. 106.—Tobin's Tube.

Tobin's Tube is a tube which passes straight through the wall from the outside and then turns upwards along the wall on the inside at right angles to it for the length of about five or six feet. It should not be longer. The opening outside is protected by a grating. Inside, near the upper end, is a handle which is attached to an iron plate inside the tube,

[1] If desired, reference can be made to ventilating grates such as Galton's and Teale's.

in such a way that by turning the handle the plate can be moved about so as to open or close the tube either partly or entirely, and so regulate the supply of air.

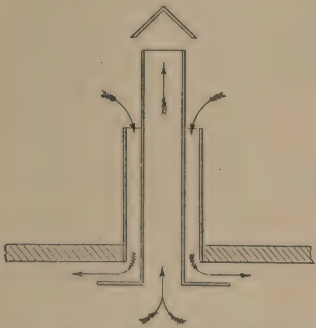


FIG. 107.—M'Kinnell's Roof Ventilator.

I have here a candle and a piece of smooth, shiny paper which I have made into a cone, taking care to cut the broad end even, and to roll the paper carefully, so as not to leave any loose edges of paper inside, which are apt to catch the air and spoil the experiment. I will also not screw up the paper at the thin end, but leave a smooth and even hole. I will now light this candle and, standing away a certain distance, I will blow at the candle with all my force, through the cone, holding it as close up to my face as possible, so that my nose and mouth are covered by the broad open end, and the narrow end is pointing straight at the candle, and quite close to it. What happens? The candle has been blown out. Now I will relight it and put the thin end of the cone in my mouth and keep the broad end close to the candle. Again I will blow as hard as I can. The candle wavers slightly but burns as well as ever. Yet the same amount of air was blown at it and from the same distance. What does this show us? It shows us that if we want to make ventilators admit as much air as possible, with as little feeling of draught as possible, we should have them narrow on the outside and wide-mouthed on the inside. Certain bricks called Ellison's bricks are made like this. They have cone-shaped passages pierced through them, and are set in the wall with the broad end of the openings towards the room.

FIG. 108.—Ellison's Bricks.

We sometimes see a ventilator in a window. It is a pane made of strips of glass like the slats of wood in a Venetian blind. These can open and shut. When open they slant forward, so that the air as it passes in is given an upward direction. There is also another ventilator used in a window, called Cooper's Ventilator. About five holes are made in the pane, and set roundways, over these, on a pivot, is fixed a round sheet of glass with similar holes in it. This sheet of glass can be turned round on the pivot so as either to bring its own holes opposite the others and so allow air to pass, or else to close them.

These are all simple ways of keeping a room fresh, but there are other ways which come under the head of artificial or mechanical ventilation, and are a little too advanced for us here. It is enough to remember that they all depend either upon drawing air into a building or drawing it out. Sometimes both systems are used together. Mechanical ventilation can be very good, and where we hear people condemning it, it is often because some mistake has been made in installing it or because it is not intelligently looked after, or because a wrong system has been chosen. The air is sometimes drawn in by a big fan, worked by a gas-engine or a dynamo, placed in the basement of the building, and care has to be taken that it is not drawn in from the level of the street or road, where it would be dirty. It is then passed through special screens to purify it, and if necessary warm it. In hot weather it can be cooled. Care must be taken in warming it that it is not made too dry. If it becomes too dry in proportion to its warmth, it will dry up the throat, nose, and skin of the people in the rooms, and perhaps cause irritating coughs. It enters into rooms usually in exactly the opposite way to natural ventilation, for it enters with considerable force from an opening near the top, and, as it enters under pressure, it expands when it enters the room, and becoming cooler and heavier drops down and should be at just the right warmth and moisture when it reaches the level of the people who are to breathe it. It goes all round the room, and passes out by a flue with an opening near the floor. This flue joins a bigger one connected with flues from other rooms, and probably some method is used to make the up-draught stronger,—sometimes a jet of steam is used as in some collieries, and sometimes fires are placed near the roof. The method by which air is drawn out of a building is called the Vacuum or Extraction method, and the method whereby it is drawn in is known as the Plenum or Propulsion system. In the House of Commons the ventilation is carried out by means of fire. A large fire is kept burning at the bottom of the great Victoria Tower, and that causes a very powerful up-draught. Pure air is drawn in through openings in the basement, underneath the House, and, after being warmed (except in warm weather) and cleaned, it passes upwards through the floor by gratings, and passes out again through openings in the ceiling, and continues to be drawn onwards by the big fire burning at the bottom of the tower and still ahead of it. Finally it passes out into the open air once more.

Artificial ventilation has some great advantages, for as the air is warmed, we can change it far more quickly than in natural ventilation without having a feeling of draught. We have learnt that in this country we cannot change more often than three times in the hour with natural ventilation, without feeling cold and chilled. But with artificial

ventilation we can change six times, or even more. That is to say, that every ten minutes all the air can be renewed. We can see how that must help health, where lots of people are gathered together, for bad air and the dust and germs it contains are never allowed to stay hanging about. It is very useful in schools, where it prevents outbreaks of measles, scarlet fever, and diphtheria. It is specially useful again in hospitals, for sick people need to have germs removed quickly and to have an extra supply of fresh air. In factories it carries off any bad smells caused by the work, and greatly improves the health of the work-people. But all mechanical systems need to be looked after by someone who quite understands the whole of his business, and carries out his duties carefully and intelligently.

In schools an excellent system of ventilation on natural lines is that in use in the Pavilion or Staffordshire type of school (fig. 109), which enables the air to be kept remarkably fresh without mechanical ventilation, and allows of thorough flushing out between classes without making the scholars cold afterwards when the class re-assembles. By this system extra means of warming are provided, in such a way that the walls are never cold, so that although every window is open wide, as soon as the class-room is emptied, and cold, pure air rushes through and sweeps away all impurities, yet, on the class re-assembling, and the openings being suitably regulated according to the direction of the wind, the rooms warm up at once. Simple as this system is, it must be used with intelligence. The hopper-windows are always open, although the others are usually closed during class time. If the wind changes its direction, it is an easy thing to regulate the hoppers accordingly. Whatever system is in use in a school, the air between classes must be thoroughly changed, and the whole room well flushed out by opening all the doors and windows wide. We remember how some of the citizen cells of the body formed themselves into lungs in order to distribute the fresh air for which all the other body cells cry out continually. A human being in a house is like a cell in the body, but he has the power of reason. He has made doors and windows to get at the air—these openings are the lungs of the house. Again, several houses together form a village or a town, and each house is like a cell in the body of the town, and therefore the town must be provided with lungs. We have to see that the streets are of proper width to give sufficient air-space, that there are open spaces for gardens and freedom for air to circulate; just as each cell in the body does harm if it does not do its work properly, so each badly looked-after room in a house helps to make the house a bad one to live in, and each badly managed house helps to make the town less satisfactory, therefore also each badly managed body, or house, or

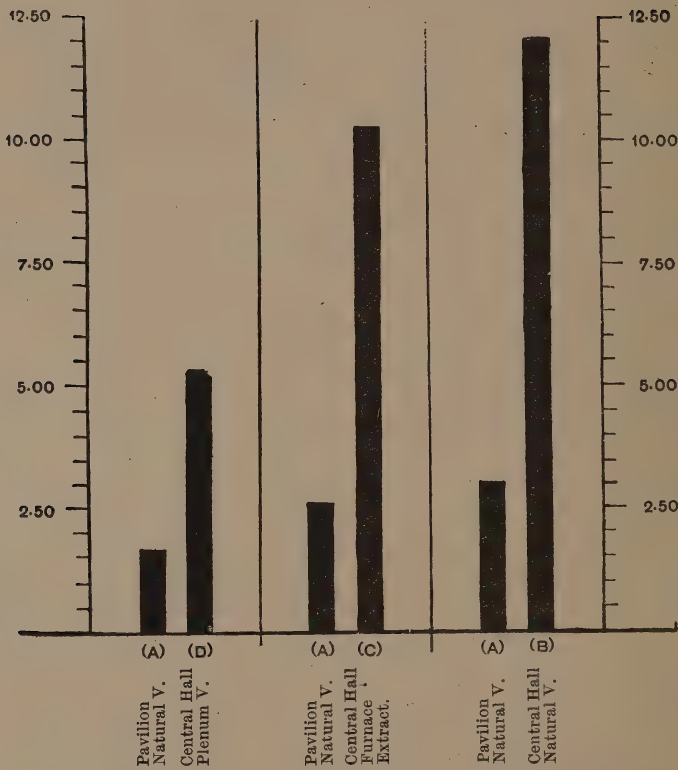


FIG. 109.—Comparison between the amounts of mean respiratory (added) CO_2 in Vols. per 10,000 found in the Pavilion or Staffordshire type of school and in schools with other systems of ventilation and built on different lines.

	Ventilation Opening per Child.	Air Changed in
	Sq. Ins.	Minutes.
Pavilion school . . .	29·6	10
Central-hall school B, . .	41·6	22
,, ,, . . .	22·2	40
		Hours (?)
,, ,, . .	13·2	3

town, or county helps to make the whole country less wise, less powerful, less healthy, less efficient, and less self-respecting, and therefore less able to do the work it has been called upon to do. Just as no single cell in the body lives for itself only, so every human being has the duty of doing his share of the work, living his life to the best of his ability, and helping others to do the same.

Blackboard Summary.

1. In natural ventilation the outlet for impure air should be near the ceiling, but the inlet for pure air should be lower down, and if special ventilators are used, they should give the air an upward direction, so that it can mix with the warmer air at the top before coming down to be breathed. This prevents the feeling of draught.

2. Ventilation openings should be narrow on the outside and broad on the inside. This also prevents the feeling of draught.

CHAPTER XXXVII.

THE BEDROOM.

Necessary Apparatus.

Large wooden box with glass front and a window in due proportion cut out at both ends. Have shutters of tin or cardboard so that the windows can be closed and made air-tight. The top of the box must have a round hole in it through which is passed a pipe or tube large enough to act as chimney for a small piece of taper when the latter is placed under its lower opening, which should come down as near the floor as a real chimney would do in proportion. Cut out also a small hole near the ceiling to act as ventilator.
Tapers.
Plasticine.
Matches.
Cork to block up the chimney.
Doll's furniture.

SOMETIMES when we go into a house, the first impression that it makes upon us is that it is healthy, bright, and cheerful. Nowhere do we find out more clearly if people really value fresh air and cleanliness than in the bedroom. It is not always people who know better who do better. Once a lecturer was going to a big town to speak on health, and she was very much pleased when she found she was going to stay with another lady who was a great student of health questions and had passed many examinations. She was therefore surprised to find that the lady lived in a dark and sunless house, and when she got into the hall she felt as if she could hardly breathe, for the air seemed so heavy and stuffy. She was shown into a drawing-room, and found it so overcrowded with furniture that there was very little room left for air, and although the weather was fine and warm, the windows were tightly closed and the whole room smelt fusty. Then she was taken to her bedroom, and as soon as the door was shut upon her she ran to the closed window to open it. But the top sash, which she tried first in order to let out the stale air at the top of the room, had never been made to open, so she had to give that up and open the bottom. But when she did so, it came down again with a run, for the cord of it was broken, nor could she find a piece of wood with which to prop it open, so she had to use a book. The next thing she did was to see if the ventilator of the grate was

open; but she found it was an old-fashioned grate without a register. "Well," she said to herself, "that ought to be all right, but the room is so stuffy that I think there must be something wrong." So she stooped down and looked up the chimney, and there she saw that it was entirely blocked up with a large sack. It amused her very much to think that the lady who had talked so much about the laws of health did not seem to take the trouble to carry them into practice.

It is very important to have a healthy bedroom, for we spend many hours out of the twenty-four shut up in it. We have learnt already so much about fresh air that we can easily see how very soon the air of a bedroom must become unfit to breathe for perfect health if door and windows and chimney are stopped up. The more furniture and the more people there are in the room the sooner will the air become impure. It is a very easy thing in a room of an ordinary shape to find out how much air there is in it for each person. We would like to have 1000 cubic feet for each one, and have two openings in the room each of the size of 24 square inches *for every person present*,—say 3 inches by 8, or 2 inches by 12, one to let out the impure air and the other to let in pure air, 48 square inches in all for each person. We should remember that the openings may have rough edges or be covered by a grating, and that will stop the flow of air to some extent, so that it is always well to allow for rather larger openings. We must also remember that we must allow 48 more square inches for each new person. For the sake of making the matter simple, we will imagine a room of a very small size, 10 feet high by 10 feet long and 10 feet wide; we should then, if we multiply these three dimensions together, find out that the room held 1000 cubic feet of air, and we should see that if we wanted to give each person 1000^3 feet per head, we could only put *one* in that room, and then we should have to have openings amounting to 48 square inches in order to keep the air pure. If we put in two people, then we must provide openings double the size. Many people have not got large enough rooms to allow each person the right amount of air unless the windows are open far more than this. The law allows the amount per head to be smaller, 600 being allowed in barracks, and as low as 300 in common lodging-houses, but if the amount is less than 300 cubic feet of air per person the law forbids it. In a great number of small dwellings, however, the allowance of air per head is even less than this, and sometimes in country cottages the overcrowding is very bad indeed, from the difficulty of getting another cottage to live in. In some crowded bedrooms the air after a quarter of an hour is really unfit to breathe, and yet people will breathe in it all night. It is no wonder that they get pale and bloodless and feel tired and good for nothing.

Now let us think once more of our little room of 1000 cubic feet

capacity, and say we are going to put one person in it with two openings for air of the size we have learnt is about what we in this country can usually stand if we do not want to have a draught. But suddenly a thought strikes us. Has this room really got 1000 cubic feet of air in it? Here is a square wooden box with a glass top; we will turn the box on its side so that the top now becomes the front and you can see in. This will represent our room. At each end I have a little window cut out, and by using thin pieces of tin which I can bend to form a hinge and nail on with tin tacks, I can make shutters and close up the window openings entirely, fastening the shutter across them so that no air can pass in or out. At the top of the room in the ceiling is an opening through which I have passed a tube which fits it closely. This tube represents the chimney of the room, and runs down inside close to the wall and ends a little above the floor where the real chimney would end. I have also cut a little hole in the wall close under the ceiling to represent the ventilator. So now, with chimney and ventilator and windows wide open, there is plenty of fresh air in the room. We will cut off a little bit of taper, about the length in proportion to the room of the height of a person breathing in it, and we will fix the taper on the floor by a little drop of wax or a bit of plasticine, and then light it. It now represents a person breathing in the room. How does the taper burn? Well and brightly. We will put two tapers in. They both burn well and brightly. Now we will shut up the windows and close the ventilator and block up the chimney, and of course as before put on the glass front and watch the two tapers. What happens? The flames are not quite so bright, they are getting smaller and rather dim. They are very dim indeed. I am afraid they are going out. Let us open this window. What has happened? The light is struggling on. Why? Because it has got a little fresh air. Why is it not better than it is, for indeed it still looks as if it might go out? It cannot get rid quickly enough of the impure air which has to find its way out slowly and with difficulty, for being hot and light it has risen to the top of the room and the ventilator is closed, so it has to cool a little and come down and get out of the window through which the fresh air is entering. Let us now unblock the chimney and open the ventilator. What happens? At once the light revives and both the tapers now burn brightly. We will now try closing part of the windows and keeping the chimney and the ventilator open. What happens? The light burns well. It evidently still gets rid of its impure air and gets enough fresh air to live healthily. That is to say, we have found out what amount of ventilation we must have in this particular room in order to give the people breathing in it enough pure air throughout the night. It is not a good plan, particularly in a small house or cottage,

to try to ventilate a room by keeping the door open instead of a window, unless it is to gain the benefit of a window on a landing outside. The reason is that the air of the warm house moves upwards, and at night is likely to be very far from pure. Try always to get real fresh air into the bedroom. Coming into some people's bedrooms in the morning is sometimes very unpleasant, so dirty and stuffy is the air, and it must be very injurious to their health.

But we asked ourselves a question before. We said "does the room which is supposed to hold 1000^3 feet of fresh air really do so?" Let us make another experiment. It seems that we have forgotten to give this poor person a bed to sleep on! Here is a doll's bedstead, we will put it in. Here is a chest of drawers, a wash-stand, a fine big wardrobe, and a chair. Here are also some clothes to hang up on this nail. Now we will shut up the windows and block the chimney and the ventilator as we did before, and light the two tapers and see what happens. Why, we have hardly closed the front before the tapers burn so dimly that it is evident they are going out at once. Why do they go out so much more quickly this time? Because there is less air in the room, for the furniture has taken the place of a good deal of it. Yes, suppose a room holds 1000 cubic feet of space and we put into it a cupboard measuring 8 feet high, 6 feet long, and 2 feet deep, which makes 96 cubic feet, we soon see that our room now only holds 904 cubic feet instead of 1000^3. So when a room is full of heavy furniture there is very often very little air-space left in it.

Let us see, then, that our bedrooms are not overcrowded with furniture; we can often turn something out with advantage. Let air circulate all round the bed, if possible. It is not good to have a bed pushed all its length against the wall. The best position is with its head against it; but if this cannot be the case, then it should stand out a little. The air-space under the bed should be kept free and no boxes should be stored there. The bedstead itself, whether of iron or wood, should be kept spotlessly clean, and no heavy curtains should hang round it. Feather-beds are not desirable, they are stuffy and cause much perspiration, which is absorbed again, and the bed is rarely opened and cleaned. Flock-beds are hard and lumpy, and it has been found that many flocks sold for bedding are in a very dirty state and more full of germs than sewage is. Wool mattresses are also not very desirable. The best kind of mattress is a hair mattress over a spring foundation. We are not nearly as particular over our mattresses in England as people are in some foreign countries. In Switzerland in the spring, the careful housewife always has all the mattresses opened, and the contents carefully picked over and left in the sun and air to sweeten before being put back into their cases. Pillows are treated in the same way.

Bedclothes in winter should be warm but also light. The very heavy cotton quilts sometimes used do not allow air to pass. Eider-down quilts should be ventilated and are of course deliciously light and warm.

On rising in the morning the first thing to do is to throw the bed-clothes back *one by one* over the foot of the bed or on two chairs. This method means that fresh air gets in between each layer and sweetens the stuffy air which has accumulated there through the night. Before the bed is made, everything must have been stripped off it, and the mattress raised in an arch so that air can circulate under it. It should be left to air as long as possible, and then the mattress should be turned over, one day from top to bottom, the next day from side to side, and the following day from bottom to top. This causes every part to be equally lain upon and makes the mattress wear evenly. It is good to put blankets in the sunshine and air by the windows, and to air the pillows also in the same way. A bed made up unaired can never be really fresh and healthy.

Always try to keep the chimney in a bedroom open. If it is an old-fashioned grate without a register and with a very wide chimney, and if the room is near the top of the house, so that the chimney is rather short and there is perhaps a very strong down draught in wild weather, then it is rather a temptation to close up the opening with a chimney-board. This should not be done, however, nor should the chimney be closed by a careful housewife because she is afraid of the grate rusting. The best thing to do is to cover up the grate so as to protect it and to stand a pretty screen in front, which hides anything that is not very pretty itself, and also, if there is too strong a down draught, the screen acts as a protection but allows air to pass. The bedroom windows should be made to open top and bottom if they are sash windows, and a dark blind often makes sleep more restful. Some people sleep very badly if the room is too light, so that if light lace or muslin curtains are used, then it is well to have a dark blind, or if a light blind is used, then dark curtains which can be pulled across to shade the room. Allowance must, however, be made for the fact that the curtains will keep out some of the air, and therefore the windows must be opened behind them wider than they would otherwise be. Some people can sleep with no blinds or curtains and do not mind the light, others, on the contrary, hide their eyes from the light in their sleep, and find on waking that they have been lying with their faces under the bedclothes and therefore have been breathing impure air. If they cannot get out of this habit, then it is far better for them to darken the room. But generally people can soon train themselves to like fresh air blowing in freely without hindrance.

Everything in a bedroom should be fresh and clean, and there should not be a great mass of hangings and draperies or a quantity of things which catch and hold the dust. The floor is best stained and polished round the edges, so that the carpet only covers the centre of the room, and can easily be taken up and the floor cleaned under it. If oil-cloth is used, it should not be glued down. A cheerful, clean, sunny bedroom, with an open chimney, a few ornaments, a picture or two, and not overmuch furniture, makes for rest, simplicity, and good health. The washhand-stand crockery should be kept very clean, and fresh water be drawn every day for the jug. The water-bottle needs special care to keep it bright. If the water in the place we live in is not very good and we have perhaps to boil it, then we ought to be just as particular also about the water we use for washing our teeth, for germs of typhoid and cholera get in through the mouth, as we know.

In a room such as we have been describing we ought to get a good, sound, refreshing sleep. Sleep is one of the greatest restorers in nature, and no boy or girl can grow properly in health, strength, and brain power unless they get plenty of it. The growing child cannot be strong and healthy if it goes to bed late and does not get proper rest. Such children feel tired and slack in the day and do not profit properly by their lessons. It is during sleep that the brain cells build up the wear and tear of the day before and lay in a stock of fresh power for the next day's work. Everything in nature sleeps and rests, not only man and the higher animals, but the lower ones also. We have learnt that organs such as the heart and lungs rest between each beat and each respiration, and during sleep the intervals of rest are longer and they are able to rebuild what is still not quite made up for by the rest taken during the day. All the work of life goes on more slowly while we sleep.

When we are asleep there is less blood in the brain, and usually more in the skin. The brain cannot sleep if it is full of blood, for then the cells become active. For that reason it is not good to learn lessons the last thing at night, nor to get over-excited, for it takes the brain some time to calm down afterwards, and sleep may come very slowly. Cold feet also prevent sleep, for they mean less blood in the feet and more in the brain. Going to bed soon after eating a heavy supper is also bad for sleep and digestion and is apt to give bad dreams. All children of school age should have nine hours' sleep, and younger children should have twelve. Grown people differ very much in the amounts that they require, but usually need from about seven to eight hours. Very young babies need about eighteen hours' sleep out of the twenty-four, and all young children should go to bed early.

Blackboard Summary.

1. It is important to have a healthy bedroom, as many hours of the twenty-four are spent in it.

2. Each individual requires 3000 cubic feet of fresh air per hour, or 1000 cubic feet will do if completely changed three times in the hour.

3. Two openings of 24 square inches (one as inlet and the other as outlet) in a room of 1000 cubic feet will secure the air being changed three times in the hour. This amount (48 square inches) should be allowed per person.

4. Rough edges and gratings prevent the free flow of air, and where these exist more space must be allowed.

5. Everything in a bedroom should be fresh and clean, and the bed well aired before being made up.

6. Adults usually need eight hours' sleep, infants quite eighteen hours, and when first born rather more.

PART IV.—SOME SPECIAL POINTS.

CHAPTER XXXVIII.

VACCINATION.

In earlier times in England, smallpox was one of the commonest diseases. It was so common that nearly everyone had it in childhood, and the grown-up people were those who had not died of it. Only about 5 per cent. of the population escaped it. In London alone, there were constant epidemics which killed thousands every few years. Dr Wilmot Evans points out that in Iceland in 1707 there had been no smallpox for many years, but when it came at last, it killed 18,000 people out of a population of 50,000 during three years. In London, during the latter part of the seventeenth century, when the population was only half a million people, there were about 5000 cases of the disease every year.

It was considered well to have smallpox when young, and get it over, as people felt so certain of having it. Servants who had not had it found it difficult to get a place. But later on it was discovered that in the East people did not have the disease so dangerously, because they adopted a practice of inoculating for it. This meant that they actually had matter from a case of real smallpox put into the skin through a small cut. This operation gave them smallpox at once, but in a mild form, and it was found that it protected them from getting it badly in the usual way.

A certain celebrated Englishwoman, Lady Mary Wortley Montagu, heard of the method when she was in Constantinople, where her husband was ambassador, and she brought the news of it to England in 1720, and had her own little boy inoculated. After that it became the usual practice, but it did not stop the disease, because, when people were inoculated, they had smallpox so mildly that they did not trouble to go to bed, and so very often gave the bad form of it to other people who

had not been treated. Nevertheless, the practice went on until a new and wonderful discovery was made.

For a long time some people had noticed that dairymaids and farmers, especially in the West of England, did not suffer from smallpox as other people did, and it was found out that many of them when inoculated did not show any signs of the disease. Some of the farmers had evidently found out part of the truth, but the honour of finding it out fully and writing about it belongs to Dr Edward Jenner, who was born in 1749 in Gloucestershire. When he was a little boy of eight years old he was inoculated for smallpox, and bled and dosed hard all the time of the treatment. Later on he studied to become a doctor, and one day he spoke to a dairymaid, who told him that she would never have smallpox. He asked why she knew that, and she replied that she had suffered from a slight illness caught from cows, called cowpox (or vaccinia), and that people who had that did not get the other. Later on Dr Jenner experimented and found that if some lymph was taken from cases of cowpox and put into a cut on the skin of a person, that person would not take smallpox when inoculated with it, for it caused a protection to be formed in the blood. This was a tremendously important discovery, and people were most thankful and grateful for it, and the practice spread rapidly. The enormous benefit was quickly realised. All it meant was a slight feverishness and discomfort for a few days, and then freedom from the dread of the awful, sickening, horrible disease which killed, blinded, and disfigured so many. It was found out later that the protection which is established in the blood wears out after a time, and that people ought to be revaccinated in later life, and it was also noted that protection depended upon the number of vaccine pustules which had been formed. For instance, a child with only one vaccination mark was found not to be fully protected.

Germany, being a practical nation, has protected herself well. She was constantly having smallpox in her midst, and she resolved to put a stop to it. Young children have to be vaccinated in Germany, and they are vaccinated again when they are twelve years old, and all soldiers are done again. Smallpox is practically never seen there now, and if doctors want to study it they have to go to other countries, and if a case does occur, it is almost always on the frontiers of Austria or Russia, for in those countries it is not compulsory.

Many people have very little idea of how terrible a scourge smallpox was among children, and what it often meant for those who did recover. As late as 1808 two-thirds of the children admitted into the school for Indigent Blind, in St George's-in-the-Fields, had lost their sight through smallpox. In 1902 not a single case of blindness due to smallpox was admitted.

During an epidemic at Sheffield nearly forty times as many unvaccinated children were attacked by smallpox as children among the vaccinated. It is possible for vaccinated children to get it, but they are much less likely to do so, and when they do, they usually have it very mildly. It is found that those with two or three vaccination marks come off best. At Sheffield, of the actual number of cases of smallpox of children under five years old, the results were as follows :—

3 deaths among each 100,000 vaccinated.

2403 deaths among each 100,000 unvaccinated.

This shows that the death-rate among the unvaccinated was 801 times as great as among the vaccinated.

During the epidemic in Gloucester, where the people had refused vaccination, the death-rate was enormous, "over 10,000 per million of the population, and the epidemic was only stopped by compulsory vaccination and re-vaccination." Only one vaccinated child died, but in the churchyard are the graves of 279 unvaccinated children.[1] Formerly, matter from one baby's arm was used for the vaccination of another, but that sometimes caused trouble from the baby not being quite healthy. Now, however, the lymph is taken straight from the calf, and the calf itself is tested first to be sure that it is perfectly healthy. The lymph is treated with glycerine in such a way that all harmful germs are destroyed. Such vaccine is perfectly pure. But we must be careful that after a baby has been vaccinated its arm is properly protected, and no dirt is allowed to get in.

The law compels people to have their babies vaccinated by three months old, but if the child is delicate, and vaccination might be trying for it, exemption can be obtained until it is stronger. People also who have what is called a "conscientious objection" can obtain a certificate and be permitted not to have it done. The objection is very often the result of not fully understanding the matter, or realising the careful way in which it is performed nowadays. Few have any real conception of what smallpox is like, and what we are saved from by having had it so wonderfully lessened by vaccination that the infection is not carried about as it used to be.

We should never forget when we hear people argue saying, "he had been vaccinated, but he got it all the same," that those people forget to say when "he" was *last* vaccinated. A man of twenty-three, who was vaccinated when a baby, may quite well take it, although he will not be likely to have it as severely as one who has never been vaccinated at all. It would be a very wise rule if everyone was re-vaccinated at twelve years old.

[1] These figures are taken from the pamphlet "Smallpox and Vaccination," issued by the Imperial Vaccination League.

Dr Wilmot Evans says, "it is not improbable that before many years an epidemic of smallpox will appear in this country, which will show the unsatisfactory condition of the enforcement of the laws of compulsory vaccination." He also says that with proper care, if the operation is performed carefully on healthy children, no harm will ever follow. The risk of any trouble is now very small, but even if it were greater it would be well worth taking.

Blackboard Summary.

1. Until vaccination was discovered smallpox was a very common disease and thousands of people died of it every year, or were blinded or disfigured for life.
2. Vaccination was discovered by Dr Edward Jenner.
3. People should be vaccinated as infants, and again at about twelve years old. They should have three or four good marks
4. Countries which have adopted compulsory vaccination without exemption have no smallpox to speak of.

CHAPTER XXXIX.

THE PREVENTION OF CONSUMPTION.

We have not spoken much about ill-health in these lessons, because we are learning how to *keep* well, not how to cure ourselves and others after we have become ill. There is one illness, however, about which we must talk a little to-day, and that is the one which people usually call "consumption," because the person who suffers from it wastes or consumes away. There is more than one kind, but the one which most concerns us is the one caused by a special germ of the rod-shaped variety, though it is such a short one that it is more like a ball when we look at it through the microscope. Its name is the tubercle bacillus, because it forms little lumps or tubercles. For this reason, the disease is also called "tuberculosis." Consumption, or tuberculosis of the lungs (phthisis), is a preventable disease, therefore we want to know how to prevent it. There is no doubt that the germ is often breathed in and is destroyed by the white blood cells, the soldiers and police of the body. These cells, as we have already learnt, can squeeze in and out of the small vessels and seize upon the invading germs and destroy them, or carry them off to lymphatic glands where there are special white cells, and there they are also destroyed, and the person whose body they are invading knows nothing at all about it and remains perfectly well.

But it is a different matter if the germs find the ground prepared. Anything which injures the health of the body and weakens the cells makes it easier for harmful germs to resist the soldier cells and gain a footing. We often hear it said of some delicate person, "he comes of a consumptive family." Sometimes we hear that several members of the family have died of consumption, and perhaps we discover that the way they are living makes it extremely likely that some more of them will follow along the same road.

People are not as a rule born with the seeds of consumption in them, but if they are born of consumptive parents, they probably come into the world with lungs that have low resisting power. Consumptive people should not marry and have children until they are quite cured

and strong; it is very wrong to bring such an infliction upon another generation. If a family shows any tendency to this illness, the members of it should put themselves into good condition, and do everything they can to strengthen their resisting power. If such people live in a bright, cheerful, sunny house, love fresh air and open windows, lead an outdoor life, and do not breathe in a dusty atmosphere, they may escape the disease entirely, and live to a good old age. But if such people go on living in the very conditions which made their forebears ill,—on damp soil, and in a damp and gloomy house; if they take up some occupation which keeps them indoors all day, and especially if it is a dusty trade; if they have constant colds, and neglect them; and if they do not take nourishing food, then they are almost sure to contract the disease, and they are doing their best to invite it to come.

Consumptive people should live with open windows day and night, and should never share a bed with another person. They should always have separate beds, and, better still, separate rooms; for husbands and wives often give it to each other, and sisters give it to sisters, brothers to brothers, and parents to their children, if they share the same bed.

Consumption is very easily cured if it is taken in time. When the germ has got in and managed to gain a footing, the lung often protects itself, if it cannot quite get rid of the intruder, by the plan of building a wall round it and shutting it up until it dies. If the person has been a mouth-breather, the lung may be irritated by dust or constant colds, and in that case it cannot protect itself so well. Even then it is easy to stop the trouble *if taken early*. It is much harder if we let the disease take hold and allow the lung to be softened by it. As the trouble progresses, the matter coughed up is full of germs, and if it is swallowed it will infect the bowels and other organs. But the consumptive person must never spit on the floor, or in the street, or in railway carriages, trams, or railway stations. As long as the matter is wet the germ is held in it, but as soon as it dries it is carried about by the air and may infect someone else. In any case, spitting is a filthy and disgusting habit, and dangerous to the health of the public.

In the house there should be a spittoon with a strong disinfectant in it. If carbolic is used, the strength should be 5 per cent., or two tablespoonfuls of carbolic to a pint of water. This must be emptied out down the drain every day and the vessel thoroughly washed with boiling water. If the person uses ordinary handkerchiefs, they should be put into disinfectant and afterwards boiled. But it is better, if a thing of that sort is used to receive the spit, that it should be something which can be destroyed at once, such as clean, old rags or Japanese paper handkerchiefs. Out of doors a pocket-spittoon bottle should be

used. All chemists keep them, and they can easily be cleaned and disinfected, as they usually open at both ends. They should always have a little carbolic or other strong disinfectant in them. A consumptive person should always hold a handkerchief before the mouth when coughing, not merely the hand. In ordinary quiet breathing, the breath is free from all germs, but in coughing they are sent out into the air, and other people may be infected. Consumptive people should not kiss children, and in no case should they kiss anyone on the mouth, or be kissed on it.

All the wise rules we have learnt for cleaning houses should be practised in a house where there is a consumptive. Dust should be *removed*, not merely raised, and should be burnt. Cleanliness, fresh air, plenty of nourishing food, especially plenty of fatty foods, together with milk, eggs, and meat, should be taken; and these, together with temperance in all things, do wonders in curing consumption. Milk should always be boiled, especially for young children, as it may contain the germs of the disease.

Young children do not as a rule suffer from consumption of the lungs, but are liable to disease of the bowels, where the protecting inner lining is not so strong as it is in grown-up people, and, therefore, is not so well able to resist the germ if it gets in. For that reason, it is always safer to boil milk, unless we know that it comes from a perfectly clean farm and dairy, and that it was milked with perfectly clean hands, and that the cow was perfectly healthy too. As we very often do not know all these things, and through whose hands the milk has gone before it reached our house, it is safer always to boil it for young children and invalids. Children are also liable to the illness after measles or whooping-cough, and should take cod-liver oil, and not be allowed to catch cold. The germ may attack joints, and cause hip-disease, and in some cases may attack the spinal cord and brain. Common sense and proper care will prevent it, therefore we must see to it that it *is* prevented.

A consumptive person's room must be disinfected after he leaves it, before it is slept in by anyone else. All carpets, curtains, and bedding should be disinfected too. The Public Health Authority will always do this. The ordinary daily or weekly cleansing of the room should always be done very carefully. Plenty of soap and water should be used, but not in such a way that the room is made damp for the sick person. Damp dusters should be employed wherever practicable, and afterwards boiled. The bedstead should be wiped daily with a cloth wrung out of disinfectant. In the bedroom of a consumptive there should be nothing which cannot be easily disinfected, or else boiled or burnt. A consumptive often becomes re-infected if proper precautions are not taken.

With simple care about destroying the spit, with fresh air, plenty of soap and water, and no sleeping together, other people need have little or no fear of infection in a healthy house. But these precautions *must* be taken, and if they are, it is probable that the extra care for fresh air and cleanliness will improve the health of everyone. Above all things, we must try for fresh air and sunshine. Sunshine destroys evil germs very quickly, and particularly the germ of consumption. It is such a fine tonic that it enriches the blood, strengthens the nerves, and makes the whole body better able to resist disease.

This is what we desire. We do not want to be afraid of germs or to have our thoughts fixed on illness. We want to think about our work in the world, and not to have to worry about how we are; worry about health is a good way to make it poor. What we have to do is to lead clean, temperate, sensible lives, for if we treat our bodies fairly, the citizen cells will look after themselves. Obey the laws of health and do not worry about it. And the laws of health are the best preventives of ill-health and the best keepers of good. They, as we have learnt, are—fresh air by day and by night, temperance, perfect cleanliness in habits, house, food, clothes, and body. They are also—dry soil, sunshine, nourishing food, pure water, proper exercise, proper sleep and rest, and proper clothing. Let us never forget, with regard to this terrible disease consumption, about which we have just been learning, that it is *preventable*, and therefore *can* and *must* be prevented. To cure it with hospitals and sanatoria is a splendid and noble work; but people must learn to help themselves more, and to hate and avoid darkness, dampness, dirt, intemperance, slovenly lives, and general unwholesome living, remembering that in consumption, as in other diseases,

"PREVENTION IS BETTER THAN CURE."

Blackboard Summary.

1. Consumption is a preventable disease.
2. Consumptive people should have fresh air, day and night, plenty of fat and milk and nourishing food, live in a sunny and dry place, and never breathe stale or dusty air.
3. The infection of consumption is in the spit, which must always be destroyed.
4. Consumptive people should never spit on the floor or on the ground, but into proper vessels, which must be cleaned and disinfected. Paper handkerchiefs can be used and afterwards burnt.
5. Consumptive people should have beds to themselves.
6. Milk for children and invalids should be boiled.

PART V.—THE CARE OF INFANTS.

CHAPTER XL.

HOW TO WASH A BABY.

Necessary Apparatus.

Flannel apron.
White curd soap.
A piece or two of fine soft flannel.
A small fine sponge.
Crushed starch, or starch and boracic powder mixed.
Powder-puff or cotton-wool.
Starch, and rolling-pin to crush it with.
Basket with pockets.
Vaseline, or zinc and boracic ointment, or lanoline.
Soft towels.
Clean, soft rags
Bath thermometer.
Soft hairbrush.
Boracic lotion, or borax and glycerine, and a cup into which to put some.
Baby's bath.
Hot and cold water.
Large, life-sized washable baby-doll, or a real baby if it can be borrowed.

A BABY is one of the most wonderful things in the world. It comes to us unable to do anything for itself, and needing the tenderest care, and it is indeed a fine thing for a mother to be able to point out the healthy children that she has reared. In olden days, when Greece was a great and renowned nation at the summit of her glory, it was not only considered a terrible sorrow, as it is to-day, if a child was lost by its parents, but it was also felt as a disgrace. To-day we are more merciful, and we know that, in spite of the tenderest care, a little child may die; but we are learning that to save the lives of babies is one of the most important works a woman can undertake for her country, and that all girls ought to know something about the care and management of infants.

First of all, we have to remember that to look after young children requires much patience and unselfishness; but these meet with their reward when we see a happy, healthy child, smiling and bright-eyed. We cannot walk through the poorer streets of any great town without, alas! seeing dirty and neglected babies, and we want to do our share to help them, by learning about them ourselves, and by passing our knowledge on to others.

One of the great dangers for babies is dirt, and so we will begin by talking about baby's bath.

We perhaps cannot say definitely, "Baby must be bathed in the morning," or, "Baby must be bathed in the evening," for a good deal depends on what suits the baby itself best, and also whether it belongs to a mother who has plenty of time in the morning, or one who has very little, and who finds it better to give a quick sponge over in the morning, and the regular bath at night. But, as a rule, it is best to give the bath in the morning, and of course *every* day. Baby should not be left to lie about for hours in its night things and only get washed quite late, but it should be attended to as early as possible.

We have learnt a great deal about the work of the skin, and we know that it is constantly throwing off waste impure matter. Perspiration, as we have learnt, consists partly of water, but also contains salts, together with fatty matter from the oil-glands. In a neglected and unwashed skin these matters get mixed up with dirt and germs, and get sour and smelly, forming a paste which helps to choke up the pores. Not only does the skin, in such a case, get clammy and sticky, but skin eruptions are very likely to break out, and also the skin will chafe very easily.

It is best to bathe a baby a little while before its next meal is due, for a bath rather tires it, and the food will refresh it and send it comfortably off to sleep. It should never be bathed just after it has had food, nor should the mother stop and feed it if it cries in the middle of being washed. Babies very often object to a good many things, and become perfect tyrants if they are given in to; so it is well to begin as we mean to go on, and then baby will soon see that it cannot have its own way, and will be all the happier for it.

We must first of all get everything ready that we are likely to want. We should not have to put the baby down, or get up and walk about with it half-undressed in our arms, to hunt for the things which we have forgotten. In the winter the bath should be placed before the fire, and we should have a screen to keep off possible draughts. It is quite easy to make a screen if we do not happen to have a regular one. A clothes-dryer, a towel-horse, or a couple of chairs with something thrown over them, will do very nicely indeed.

If we can get it, we should always use rain-water for baby, or at all events the softest water we can get. If the water is hard, it is a good plan to put some oatmeal in a muslin bag and let it soak in the water overnight. The plainest white curd soap, such as we have here, is one of the best to use. Never use strong soaps, or highly coloured, or scented ones. We shall want a piece or two of fine, soft flannel. I have some here. And if we can afford it, we can have a small fine sponge, which must be kept very clean and free from old soap. We may want some powder, so here is a box of starch powder and a powder-puff, or instead of a puff, a piece of clean cotton-wool, pulled out to make it light and fluffy. This is a cheap and clean thing, for we can burn it and get a fresh piece. We can use a powder made of one part of boracic powder to two parts of starch, and we can break the starch up fine ourselves by rolling it with a rolling-pin. It is a good plan to have a basket which, if we like, we can trim prettily, and in it we shall keep the things that we want for baby's bath-time. In it we shall have the soap, sponge, and flannels, and keep them in a separate part where, if they are at all damp, they will not make anything else so. We shall also have a little pot of vaseline, or some mixed zinc and boracic ointment, or perhaps a tube of lanoline; and we shall want some soft towels for drying baby, and some soft, clean rags,—bits of clean, old handkerchiefs will do, if fairly fine. These are for cleaning out its mouth. We may also have a soft brush for baby's hair, some safety-pins, needles, and white cotton; and one of the needles must be threaded ready and put in a safe part. This is for sewing on the binder. Baby's clothes should also be put ready in the basket, neatly folded, the ones which will be first wanted being uppermost. We ought also to have a bath thermometer,—one can be bought for sixpence.

We shall also want a little weak, cold boracic lotion by us. We can make a big bottleful in the proportion of one teaspoonful of boracic to a pint of boiling water. We must use a very clean bottle, and cork it well. Sometimes we use glycerine and borax, but it is not necessary unless baby has really got a sore mouth, which it is our hope it never will have if we look after it properly. We must have a little of the lotion in a cup by our side.

Now about the bath. If baby is very young, we can use a big basin; but if it is a little older, a zinc bath will do nicely, and we can place it on a chair or stool in front of us. First of all, we must see that the doors and the windows are closed, and that there are no draughts.

Whoever is going to bath baby should wear a thick, warm, flannel apron, and be seated on a low chair, so that her feet are firmly planted on the ground, with the knees even and not sloping. To raise the feet on a stool is not so safe, as sometimes a stool slips or is stumbled over

on getting up. The stool or chair on which the bath is placed should be conveniently low, so as to avoid much stooping.

With baby lying on our lap, we take a little bit of the soft, clean rag, which has been dipped in boiled water, and putting it over our forefinger, we go quickly and very gently over the inside of the mouth, wiping the roof, gums, and tongue. This only takes a few seconds, and should be done morning or evening. It prevents thrush, which is a disease caused by a germ which attacks babies whose mouths are left uncared for. Burn the rag. If baby has a breaking out from thrush, then glycerine and borax should be used. This can be got from the chemist, or prepared at home in the proportion of a teaspoonful of the powder to a tablespoonful of pure glycerine. If a baby's mouth is wiped out gently after each feed, it is never likely to suffer from thrush; but we can imagine that our mouths might not be very nice if, like a baby, we had very little water in the mouth and lived always on milk, which clings to the skin and is apt to go sour. Almost unconsciously the movements of our tongues round our mouths helps to keep them free from food matters. Great care must be taken not to injure the delicate lining of the baby's mouth.

We must take a baby's clothes off gently, and also turn and move it as gently as possible, never pulling it about by its arms.

The bath is ready, we put the cold water in first, and then add warm until we see by the thermometer that the temperature is 100° F. Next we take a piece of soft flannel, or the little face sponge, and wash the face very carefully, taking special care of the eyes, nose, and ears. Then we put this sponge or flannel away, for we use it only for the face, and we take another flannel, and go on washing baby on our lap, soaping the little body all over, including the head, taking care to go well into all the creases of the neck, and into the armpit and the folds of the thighs (groin). It is often best to do this with the hand instead of a flannel. Now we will look at the thermometer and see whether the water is still warm enough, and if not, we must add a little more of the warm water which we have by us ready. It is not wise to trust to feeling the water by our hand, for if the hand is hot or cold, the water feels quite differently to it and may give us quite a wrong impression, and baby be either scalded or chilled. If we should happen not to have a thermometer, the safest way is to put the point of the elbow into the water, for that part of the body alters its temperature very little. The water should feel *just warm*.

Now baby must be lifted and put into the bath. The left hand and forearm must be slipped under the head and backbone, which should be well supported by them, while the ankles are held by the right hand by slipping the forefinger in between them and holding them together by

the thumb and other fingers. In this way the soapy little body will not slip. We must keep the head well up and support the back and the neck firmly while baby is in the water. We use plenty of water, and dip baby right in nearly up to its neck. If we hold the child gently but *firmly*, it will love being in the water, and soon get to splash and kick ; but although we do not want to hurry, yet, in the very early days, it must not be kept in more than about a minute. As it gets a little older it can stay in longer and splash about, and the last sponging can be made with colder water ; and later on it can finish up with quite cold water in the sponge, which is very strengthening, especially for its back.

We now slip a nice warm towel on to our lap, and lift the baby out on to it and wrap it up and dry quickly and carefully, once more taking care to go into all the creases. It is a very bad plan to dry carelessly and trust to powder to clear off the damp, for that leads to the powder getting into little hard lumps and irritating the tender skin. A well-dried baby does not need much powder. Indeed, if powder is put on round the thighs it is very apt to get into hard lumps when the napkins are wetted. It is better to smear the buttocks and groins with a little vaseline, or a cream made of equal parts of zinc ointment and boracic ointment ; this prevents any chance of soreness. When a baby is being dried, we can turn it over on to its stomach and, after drying it, rub its little backbone and legs gently with the warm palm of the hand. If the room is warm, baby will thoroughly enjoy being allowed to stretch and kick about for a little, which is very good for it ; but we must take great care that it does not catch cold.

If baby's head gets a little dry from washing, we can rub on a little vaseline. We must always be very careful about a baby's head to protect it from injury, for the bones have not yet quite joined together but are still quite soft in places. There is one particularly well-marked place on the top of the head in front (anterior fontanelle). This open part, covered over with soft tissues, gives the brain room to grow, and a baby's brain grows very quickly. This opening in a healthy baby does not show very much, but in a weak, sickly one it is often very plain indeed. Some ignorant people have been known to say that we must not wash a baby's head, because we might give it water on the brain! We know better than that, and that water on the brain comes from inflammation inside. Sometimes we see little babies with very dirty heads, because their mothers are afraid to wash them, on account of some mistaken idea or other. But we know that dirt breeds germs, and germs breed disease ; and we intend to get rid of the danger, by seeing that any baby we have to do with is kept beautifully clean and sweet.

Blackboard Summary.

1. It is very important to keep a baby's skin clean, otherwise salts in the perspiration and the natural oil will mix with dirt and germs and choke up the pores, and keep the skin damp, clammy, and unwholesome.
2. A neglected skin leads to skin eruptions and chafing.
3. Get everything ready for the bath before you begin it, and always beware of draughts.
4. Undress, gently wash face and ears, nose and eyes with special flannel. Soap all over, while on the lap, with Castile or plain curd soap, going into all the creases.
5. A baby's mouth must be kept clean.
6. Support baby's head and back, and put it into the bath at 99° or 100° F. Test with thermometer or point of elbow. Sponge off soap thoroughly, and lift out and dry gently. Use a little powder for the creases, but ointment may be best for the thighs.
7. If the room is warm, let baby enjoy a good stretch and kick.
8. Dirt and germs bring disease, so baby must be clean in body and clean in clothes.

CHAPTER XLI.

CLOTHING OF THE INFANT.

Necessary Apparatus.

- Baby's basket.
- Safety-pins.
- Soft, knitted, wool binder, or one made of soft flannel, four inches wide and a yard long.
- Needle and white cotton.
- Soft, knitted, Shetland-wool vest.
- Round-pointed scissors.
- Turkish-towelling napkins.
- Flannel pilch.
- Long flannel.
- Cotton gown.
- Nightgown.
- Knitted boots.
- Dresses suitable for summer and winter, short coats, winter and summer outdoor dress, etc , etc.

Now that baby is washed and dried, comes the question of dressing. An infant's clothes should always be simple in shape and easy to put on, for a baby should not be turned over often or pulled about a great deal. For that reason, it is best that the clothes should fasten either all in front or all at the back. Sometimes we find the poor baby being turned over and over and pulled here and there, till it is no wonder it cries from being tired and cross.

First of all, we have here a little soft, woollen vest, made of Shetland wool, and with long sleeves. These are much better than cotton shirts, especially in winter, and the wool is so fine and soft that it cannot possibly irritate baby's tender skin. But before we put on the vest we must put on the binder. Stiff, hard binders are bad for babies; they cramp the inside and very often press on the liver, and may cause indigestion and a form of jaundice. Some people like to put them on because they not only think them correct, but they like to feel something firm and hard to catch hold of and help them to prop the baby up. But remember that a baby should never be carried sitting up till it is at least five months old. It should take its airing lying down. It is a sad sight to see a tiny baby carried along, sitting up, its head

wobbling from side to side. A baby's backbone is very soft and not properly formed, and sitting up too early prevents it from growing properly. We shall therefore never use the stiff, hard binder. A very good one to use is a knitted one, four inches deep and about a yard long. It must be made of soft wool. If flannel is used, it should also be soft; and out of a yard, three, if not four, binders can be made. It is very important indeed to keep the belly or abdomen of a baby warm, for a chill there may mean bad diarrhœa and may cost the child its life. We have the binder rolled up ready, and we begin by undoing a little bit and laying this loose end across the child's body, binding it gradually round, by pushing the roll underneath. We need to pull it gently but firmly; it must not be so tight afterwards that you cannot get three fingers underneath if you try. Fasten it by sewing it with needle and thread, taking care to put a finger underneath so as to be sure not to prick the baby. Cut the thread with a pair of round-pointed scissors. Never use sharp-pointed scissors for a baby, for it may move suddenly and hurt itself against the points.

Now we slip on the little soft, Shetland-wool vest. We knit this very loosely so that we can easily slip it over the head, or we can make it to open and lap over in the front; it only comes down as far as the hips, for we do not want it to interfere with the napkins. Baby will need at least three or four of these vests.

The napkins must be made of very soft material,—Turkish towelling is very good, for it absorbs wet well and yet does not get hard and cold. A napkin is necessary for young babies, but good habits should be taught them from the first. If they are "held out," they soon get to understand, and motions and water will be passed. These good habits mean that the napkins will not need to be changed so often, and the baby is kept drier and more comfortable, and is less liable to soreness. We ought to have from a dozen and a half to two dozen napkins at least, and more if we can afford them. Dirty, wet, soiled napkins must be taken off as soon as possible. Wash the baby clean, and put a little vaseline or other ointment on the skin; this is better than powdering. Never dry a napkin that has been taken off and then put it on again without washing it. The napkin is *not* clean because it is dry, and the salts and ammonia left behind after the drying will smell unpleasantly, and be very irritating to the skin. Keep a zinc bath for the soiled napkins, which must not be allowed to get dry, but should be roughly washed out at once and put to soak in plain water. Later on, wash well, using Fels-naptha or paraffin soap, or else wash in hot suds and boil for about a quarter of an hour. Rinse well in fresh water, dry thoroughly, and iron. *Never* put a damp napkin on a baby. Never use soda when washing a baby's napkin; it chafes the skin.

Besides napkins, a baby wants flannel pilches. These are made three-cornered in shape, and are put on at night, over the other napkin, or when the child goes out. Very often these can be made out of old shirts or petticoats, and so save expense. It is a good plan to scoop them out a little, so that the part which comes up between the thighs is not quite so clumsy and thick as it otherwise would be.

The next thing which baby will want is a long flannel; it will want three or four of these among its clothes. See that the flannel comes high up and covers the tops of the lungs well. It should be box-pleated at the back, and fold over double in front, and fasten with strings. In this way, there is a double part to protect the lungs back and front. Long flannels should come well below baby's feet, so that they can, if so desired, be turned up with a safety-pin over the feet and legs when going out in cold weather. It takes about a yard and a half of flannel, twenty-seven inches wide, to make a long flannel, and we should want about six yards of binding and a little soft ribbon for strings. If the weather is very cold, the baby may need two flannels; but a better plan is to button a flannel skirt on to the waist of the other, for otherwise two long flannels make the baby's body very clumsy. It can always wear an extra little woollen vest or coat outside its dress if it needs more covering.

Next comes baby's dress. The day gowns should be made of cotton, for cotton can be easily washed. Longcloth or soft nainsook will do; and it is best not to trim the little frocks round the neck, as the lace is apt to irritate the skin. In winter we can use thin woollen material, such as nun's veiling or Viyella. Never use flannelette for an infant. A coroner holding an inquest on a little baby once said, that the wearing of flannelette, the want of fireguards, and the habit of not dressing babies till the middle of the morning were responsible for most of the accidental deaths among them.

On its feet, the baby should wear soft little bootikins of knitted wool. It is *very* important to keep the feet warm.

You notice that we have used woollen things for baby for the most part. If you remember our lessons on clothing you will know why. Wool prevents the baby from losing its natural warmth, and also absorbs perspiration, and so prevents chills. Wool is a slow conductor of heat. We wear wool to keep our own warmth in, and we wrap ice in flannel to keep the warmer outside air from getting at it. We want, however, nice, soft, woven or knitted woollen materials which catch and hold air between the fibres; for air, as we also learnt, is a slow conductor. A soft, loosely-woven garment, holding plenty of air, is therefore warmer than a more tightly woven one of the same weight of wool. It also absorbs moisture much better. Notice also

how careful we are to keep baby's chest, stomach, arms, and legs warm. There are big blood-vessels in the arms and legs, and if the blood in them is chilled, it goes on down again into the depths of the body and perhaps chills the stomach and lungs, and so does great harm. It is amazing how often people let tender little babies have bare arms.

Babies should be sensibly and warmly clad, but should never be coddled. Some children are so overloaded with clothes that they are kept in a bath of perspiration, which is very weakening for them.

At night a baby ought to have woollen nightgowns; but if the expense is too great, then calico ones, with a woollen vest, should be worn, but not the same one it wore during the day. It will want at least three or four nightgowns. It will also want a soft shawl or two to put round its shoulders while indoors, and a big warm one for outdoors over a little woolly jacket. The bonnet should be made of wool, and cover in the head, neck, and ears. It should fasten with soft, silk strings. Never use elastic for a baby. A veil is not necessary, unless there is a high wind or a fog, and baby has to go out in it.

We have only been talking about long clothes so far; but at about three months old the baby is put into short coats, for it is beginning to get very lively and to want to move its legs about more. Just as we do not make the long clothes too long, so we do not make the short clothes too short. They should come down over the feet a little, and the frocks should be of washing material, and made with high necks and long sleeves. The baby will want flannel petticoats and outer petticoats and little pinafores. Never use flannelette, if you can help it, even when baby is short-coated, for it is not so warm and wholesome as wool, and the cheaper kinds are terribly dangerous; if any is used, it should always be the "non-flam" kind; but it is safer not to use it at all for young children. The little bootikins can now be made with longer legs, and be tied by having ribbon run in below the knee and round the ankle. If we follow out these rules, and make simple clothes of good materials, well cut, well made, and keep them well washed, and sweet and clean, then baby will be happier and healthier and look much better dressed than many a child we see decked out in unsuitable, showy, and uncomfortable garments, which only too often are far from being either fresh or clean.

Blackboard Summary.

1. A baby's clothes should be light, warm, and simple, and should cover the lungs, arms, and legs. Fine woollen vest with long sleeves, woollen binder, long flannel with sleeves in winter, and without sleeves

in summer, and a simple dress, are enough with warm shawl and knitted boots.

2. Never wash baby's napkins in soda. If they are wetted and taken off, do not just dry them and put them on again. This habit is dirty and makes the skin sore.

3. For out of doors, when very small, wrap baby up in a warm shawl and put on a warm soft bonnet.

4. Let baby's clothes be dainty and pretty, but simple and good. No imitation finery.

5. Use wool or cotton, *but not flannelette.*

CHAPTER XLII.

BABY'S FOOD.

Necessary Apparatus.

Fresh milk.
Jugs, basins, etc.
Boiling water in a deep pan.
Boiling water in a kettle.
Materials for making (1) Barley-water, (2) Limewater, (3) Oatmeal-water.
Good and bad kinds of feeding-bottles.
Large basin.
Borax.
Brush
Specimens of infants' foods.
Dilute iodine.
Test-tubes.
Lamp or Bunsen burner.
Whole and skimmed, condensed and sterilised, preserved milk of various brands (show the labels).

PART I.

We have been learning about washing and dressing a baby, and to-day we are going to talk about its food. Thousands of babies die every year in this country, for no other reason than that they are wrongly fed. Thousands more die from other reasons; but an enormous number die from this one alone. It is terrible to think of such a thing, for we must remember that *no babies ought to die.* We have learnt a great deal about how to make people healthier and live longer. Laws have been passed which have had a most wonderful effect. A far greater number of people live to be old, and they keep young longer. At every age of life but one, there has been great improvement, and that one is *the age of infancy.* Babies die in almost as great numbers as ever. During the last few years there has been an improvement; for doctors, nurses, inspectors, lecturers, health-visitors, and teachers in all kinds of schools have worked very hard; the public bodies have striven to teach people better ways and to set wrong things right, and so have many private individuals; but the death-rate still remains terribly high.

A tiny child comes into the world, and before it lies a long road—

the road of life. Imagine it! with milestones set for every year; and follow it in your mind's eye till it is lost to sight. Down that road of life go the travellers; and it has been computed that in these days, with healthy living, they ought to reach the hundredth milestone. Few do that; but all have the right to expect to get halfway. There are nearly a million children born every year in this country. All those ought to go a long way along this road; but about 100,000 of them never get beyond the first milestone. Instead of a million children, let us think of 100,000,—born, let us say, last year. How many of these are going to be men and women? All of them? *All of them ought to*, but from 16,000 to 17,000 of them will never see the end of their first year. About 25,000 will not see their fifth birthday. The long road of life stretches away, but their feet will never tread it. There is something very wrong about this. The British Empire now, more than ever, needs all its children. We must try and do *our* share in saving some of these poor little babies.

Why do the children die? There are many reasons. Anything which makes the health of the father and mother bad is likely to make their children delicate. We must live healthy, self-respecting lives. A fearful enemy is strong drink. Mothers who drink hard are likely to have poor, sickly children; and in a home where either father or mother drinks, the children are likely to suffer from negligence, and often from want of proper food and clothing. Some kinds of work, too, such as working where lead is used, is not good for women, as it affects the health of their babies.

More children die in towns than in the country, and the chief thing that they die of is *diarrhœa*. Seven times more children die of it in the towns than in the country; and well over three-quarters of our population live in towns,—therefore we must see that towns are made as healthy as possible. It is well known that diarrhœa is a disease mostly caused by dirt. *Dirt!* Think of it! Dirt where? *Mostly in the food.* What is that usually due to? It is due to *ignorance and carelessness.* Lung trouble also is the cause of the death of many babies; and troubles caused by giving the wrong *kinds* of food. So the chief troubles we have to guard against are *wrong feeding, dirt, and cold.*

The best thing for a young baby is to be nursed by its own mother. Nature has provided the right kind of food for the child, containing the right things to build up its body, in the right proportions and at the right temperature. There are no harmful germs in mother's milk, and it cannot go sour. A baby ought to be nursed by its mother for six months if possible, and not longer than nine months. The first three months are the most important of all, for it is during them that most young babies die when artificially fed. Remember, no matter

how carefully other food may be prepared, it is not the same as what a healthy mother can give her child; and a baby nursed by its own mother has a far better chance of growing up tall and strong. The food comes straight to the child's mouth; it has not been milked from a cow by someone who perhaps has not got very clean hands. It has not been carried by train or cart, or kept in a shop. It has not been put into different vessels, and perhaps finally into a dirty, or at least not properly washed jug, as so often happens in careless homes. It does not go through the danger of being kept too long, or in a place where the flies can get at it. No, it is just right as regards purity and warmth and strength, and it alters as the child grows older, so that it suits the older one as well as the younger one. The mother who nurses her own child avoids the difficulties and dangers of bottles. During the Franco-Prussian war of 1870, when Paris was besieged, and food of all kinds was very hard to get, people expected that the babies would suffer; but to their surprise it was found out that far fewer babies died; and the reason why was because artificial foods and cow's milk were not to be had, and the mothers had to nurse their babies themselves.

When a mother has nursed her baby for about nine months, it is time she should begin to wean it. The weaning should take about a month.

WEANING.

Hours.	1st Week.	2nd Week.	3rd Week.	4th Week.
5 a.m.	Breast	Breast	Breast	Breast
8 ,,	Milk	Milk	Milk	Milk
11 ,,	Breast	Breast	Milk	,,
2 p.m.	,,	,,	Breast	,,
5 ,,	,,	,,	Milk	,,
8 ,,	,,	Milk	Breast	,,
11 ,,	,,	Breast	Milk	,,

If, however, a mother cannot entirely nurse her child, she can perhaps partly do so, and that is better than not doing it at all. It is quite a mistake to think that cow's milk cannot be given to a child if it is being nursed by its own mother. It must, however, be carefully altered, so as to be as much like the mother's milk as possible.

If a mother cannot nurse the child *at all*, then the next best thing for it is good cow's milk altered to suit it; and it should have no other food till it is about eight months old. It is not always easy to get good cow's milk, but we must always try our best, and we ought to get it fresh twice a day.

Here is some fresh, sweet cow's milk which has been put into a very well scalded earthenware jar. On the fire I have a deep pan of boiling water. We will put the jar into the pan, and let the water boil round it for a quarter of an hour. By doing this the milk cannot boil over or be burnt. The cooking destroys most of those germs which, having got in from the outside, are waiting to turn it sour. Now, if we can cool it quickly, by letting the tap run over the outside of the jar, or by standing it at once in very cold water, it will keep sweet much more easily than if it had been allowed to cool slowly. We will now scald out this jug (or basin) and be sure that it is spotlessly clean, and then we will pour the milk into it and cover it up and put it into a cool airy place. *Never* give a baby uncooked cow's milk, unless you know all about the health of the cow and the dairy the milk comes from and can be sure it is free from disease germs. *Never* use skimmed or separated milk. *Never* let flies get at the milk.

We remember that milk is a complete food, and that it contains all the proximate principles of food which are necessary to build up the body and to give heat and power to do work. Cow's milk has, however, too much body-building material (casein) for a baby, because it is meant for a big animal like a calf; so for a young baby we must always add water to make it less strong. But the fat in cow's milk is not very much more than in mother's milk, so that when we add water we make it too poor in fat, which is very important, especially for the proper growth of the nervous system. We shall have to add some more cream. We shall also have to add sugar, for cow's milk is poorer in this than mother's milk.

DIFFERENCES IN PROPORTIONS.

	Mother's Milk.	Cow's Milk.	Half Water and Cow's Milk.
Proteid	$1\frac{1}{2}$	3	$1\frac{1}{2}$ (right)
Sugar	$6\frac{1}{2}$	$4\frac{1}{2}$	$2\frac{1}{4}$ (too little)
Fat	$3\frac{1}{2}$	4	2 (too little)

For every six ounces of the mixture we must add two teaspoonfuls of cream and two level ones of sugar. But even then the altered cow's milk does not always agree. We found out when we were studying milk that it formed a thick clot in the stomach. Mother's milk does not form this hard clot, which is difficult for some babies to digest. In that case, the undigested milk irritates the stomach and bowels, and may cause diarrhœa or, in severe cases, convulsions. For that reason

we may have to use something which causes the milk to form a softer clot. Barley-water will have this effect.

We may have to use this barley-water in the place of plain water, but if it makes the child's bowels too loose, we may have to put in a little limewater. Two teaspoonfuls to a feed instead of the same amount of barley-water will probably be enough; but where there is a tendency to diarrhœa, we may have to leave off the barley-water entirely and use half plain water and half limewater.

Remember that a baby's stomach is very tiny and only holds a few teaspoonfuls at first. If it sucks more than it can hold, it brings it up again, for there is no room for it. Babies are made sick very easily: do not shake a baby about and jig it up and down just after it has been fed. If you do, you only churn up its food and probably make it sick. It is a great mistake to feed a baby every time it cries. It is an excellent way to spoil its digestion and its temper. Babies cry from other causes than because they are hungry. A baby may cry because it is thirsty, and a teaspoonful of cold, boiled water may make it quite happy if it cries before its meal-time. It may cry because its feet are cold, and this is a very common reason. *Warm them.*

It may cry from indigestion, from having a wet napkin, from colic, from a pin pricking it. In each case we must try to find out the real reason. Always boil the water you use for baby's food.

It is very hard to say how much a baby should take at each meal, for this varies with the baby, the house it lives in, the climate, the clothes the child wears, etc. Generally an overdressed baby in a hot room will require less food than a properly dressed baby who lives a good deal in the fresh air; but, roughly speaking, the following tables give a fair idea of the amount the baby will probably require:—

Quantities of Food suitable for a Healthy Child.

Age of Child.	Milk.	Water or Barley Water.	Total Amount to be given at each Meal.	Feeds per 24 Hours.
During 1st fortnight	1 tablespoonful	2 tablespoonfuls	3 tablespoonfuls	9
,, 2nd ,,	2 tablespoonfuls	3 ,,	5 ,,	9
,, 2nd month	3 ,,	3 ,,	6 ,,	9
,, 3rd ,,	4 ,,	4 ,,	8 ,,	8
,, 4th ,,	4 ,,	4 ,,	9 ,,	7
,, 5th ,,	5 ,,	4 ,,	10 ,,	7
,, 6th ,,	6 ,,	4 ,,	12 ,,	7
,, 7th ,,	8 ,,	4 ,,	13 ,,	6

ANOTHER AND SIMPLER TIME CHART.

Infant's Age.	Meals per 24 Hours.	Commencing	Interval between Meals.	Quantity per Meal	Total.
		a.m. p.m.			
1st four weeks .	10 feeds	5 – 11	2 hours	1–2 oz.	10–20 oz.
During 2nd month .	8 ,,	,,	$2\frac{1}{2}$,,	$2\frac{1}{2}$,,	20 ,,
2nd to 9th ,,	7 ,,	,,	3 ,,	3–6 ,,	21–42 ,,
10th ,,	7 ,,	5 – 10.30	3 ,,	6 ,,	42 ,,
11th ,,	6 ,,	,,	$3\frac{1}{2}$,,	7 ,,	42 ,,
12th ,,	5 ,,	5 – 10	4 ,,	8 ,,	40–45 ,,

Two tablespoonfuls make a fluid ounce.

Now these tables arrange for the baby to be fed every two hours at first; later the interval between the meals is two and a half hours; and when the child is three months old, if it is a healthy baby, it should not need to be fed oftener than every three hours. Doctors, however, who have been studying babies very carefully tell us that when the baby is strong enough it is better to begin with an interval of three hours between meals, so that the child may easily get into the good habit of three-hourly feeds during the day; and at night (9 p.m. to 6 a.m.) only one or no feed,—this for bottle-fed as well as breast-fed babies.[1]

This longer interval gives the stomach the chance of resting between meals; and we know, like other workers, the organs of the body need rest. A tired stomach will not do its work properly; therefore we should try to teach the baby as soon as possible to sleep quietly during the night, and not expect food in the day oftener than once in every three hours.

We often cannot keep exactly to the proportions given in tables; for what suits one child does not always suit another, and we may have to alter the food a little till we get it just as baby likes it. But we must never forget that a child must be fed regularly. "Feed the Baby by the Clock, not by the Cry" is an excellent motto to remember. Baby soon becomes a tyrant and wants food at all times; but he is not any better or happier for being indulged; while his poor mother is made a slave to him. It is very bad for the digestion to feed at irregular intervals.

[1] With the longer interval the quantity at each meal may be slightly increased, so that the child is still consuming the 10 to 40 oz. per twenty-four hours according to its age.

Part II.

What kind of feeding-bottle are we to use? *Never* use the old-fashioned long-tubed Alexandra feeding-bottle. It is very dangerous, and is forbidden by law in some wise countries. It is impossible to keep the tube really clean, for even with the very greatest care, germs grow inside, and may give the baby diarrhœa. The best kind is a round one like the Sohxlet, or a boat-shaped one like these we have here, with tablespoonfuls marked on the outside, and without any tube, simply with a rubber teat pulled over the top. This boat-shaped bottle has a plug at the lower end, and we can scald it out thoroughly and let a stream of water run through. We must turn the teat inside out, scrub it clean, and scald it. It is best to buy a new teat every month, for even with every care they get unpleasant if kept too long. When the bottle and teat are perfectly clean, we put them into a clean basin with boiled water, into which we have put half a teaspoonful of borax, and we keep them there until they are wanted, and then we rinse them in clean water before using them. It is well to have two bottles and use them in turn. If we use a brush to clean them with, we must scald the brush afterwards.

See how necessary it is to be careful. I will pour some milk into this bottle and pour it out again and rinse it quickly and rather carelessly. What do you notice? The bottle is not quite clear when we hold it up to the light and we can see quite well that there is a thin smear of milk on the glass here and there. *That milk will grow germs which will get into the clean fresh milk which will be put in at the next feed.*

Another way of preparing milk for a baby, is to get ready a certain quantity at once, by mixing the water, milk, and sugar together and then boiling them, putting the mixture into a clean jug, and *covering it over with a cloth.* We then take out the amount we require each time and cleanse the bottles as we have learnt. If the baby does not finish its bottle, do *not* keep till next time and warm it up again. Throw it away and take a fresh amount, for germs grow easily in milk warmed up to blood-heat, as this has been. Each feed for the baby must be heated up to 99° F. by putting the bottle, when the food is ready, into a bowl of hot water. Shake the bottle slightly, so as to mix the warm milk well together, and take the temperature with a clean thermometer, or else by pouring out a little of the milk and tasting it. We do *not* ever put the teat into our own mouth, for we might have bad teeth and so give harmful germs to the baby. Also the germs of diphtheria have been found in the mouths of people who have been apparently quite well and who have not been

harmed by them; but they might harm the baby. It is much cleaner and safer to test in the way I have said. The boat-shaped bottle has to be held by the nurse or mother, and that seems to people to be a great disadvantage over the long-tubed one. It is not so really, however, for it saves trouble in the long run. For instance, if we are watching the baby take its food, as we have to do with the tubeless bottle, we can check it at once if it takes it too quickly, and so we prevent a fit of indigestion. But if the old-fashioned bottle is used, and the baby, as is so often done, left to lie down and suck by itself, it may take it very rapidly and get the wind, or go to sleep with the feed half done and wake up and finish it when it is cold and so perhaps get a colic; or it may suck away at the empty bottle, which will also be likely to give it windy colic. A baby ought to feed lying on its side, which is the natural position when it is nursed by its own mother. This position prevents it from the danger of choking if it should be sick, and it usually has to lie in this position if it is fed by the tubeless bottle.

A baby should take from a quarter of an hour to twenty minutes to take its meal.

As cow's milk altered with water to suit the baby is poor in cream, we have seen that it is well to add two teaspoonfuls of cream to every six ounces of the food, after the water and sugar have been added. Of course cream is expensive and everyone cannot afford to do this. We will consider a cheaper way of giving fat later on. A simple and easy way to give the extra cream, is to get a pint of good milk in the evening and let it stand till morning in a clean bowl, covered over with a clean cloth or a plate, and put the bowl into a basin of cold water to keep it cool. In the morning we must get half a pint of fresh milk, skim two tablespoonfuls of cream from the milk which has been standing all night, add it to the fresh milk, with a teaspoonful of sugar, a pint of water, and as much cooking-soda as will lie on a sixpence, and then scald, cool, and keep in the manner we have learnt. This will have to last for twenty-four hours, and therefore, in warm weather, it should be scalded again, first adding a little drop of water to make up for the water it will lose on being heated up for the second time. The cooking-soda prevents the formation of the heavy curd. When cream cannot be got, then cod-liver oil can be given instead, about thirty drops at a time, and twice a day, or it can be divided into three doses of twenty drops each and added to the feeding-bottle.

As baby gets older, it needs less water and more milk in proportion. At six weeks old it will be taking half milk and half water, and instead of three or four tablespoonfuls at a time, it will have the amount increased gradually until it is taking six; and at three months old it will be taking about eight tablespoonfuls per meal. The strength of the

milk is gradually increased in this manner, until at seven months old it is taken pure.

We must never give a baby "what we eat ourselves." It is a very foolish and ignorant thing to do, and shows that we do not know our business. A baby's stomach and bowels are not meant by nature to digest anything but milk; and yet you see people giving their babies pickles and cheese and herrings and biscuits, and accustoming them to expect such things. It is dreadful to see how the health of babies is spoilt in this way.

Patent foods are usually not nearly so good for babies as good cow's milk, besides being very expensive; and, if such foods are used, it must be one of those which contain no unaltered starch, for babies under seven months old have not usually the power of digesting starch properly. We have learnt before how to test for starch, and we will take specimens of different kinds of babies' foods and see which contain it and which do not. Some are mainly dried milk, and those are the best.

Where is starch first digested? In the mouth. What happens to it there? It is turned into a form of sugar. We have seen that starch does not melt in warm water as sugar does, but that there is something special in the water of the mouth which can turn it into sugar, in which form only it can soak through the wall of the bowel and get into the blood and nourish the body. In the stomach, starch is not digested by the gastric juice, which is the particular digestive juice found there, but it may be digested a little for a short time by some of the water of the mouth which may have been swallowed with it; but the acid gastric juice soon checks that, and so it has to wait to be all turned into sugar by the digestive juice it meets when it passes out of the stomach and gets into the small bowel. From there it all passes into the blood by soaking through the walls. *Now babies under seven months old, before they have begun to cut their teeth, have not got the power, either in the mouth, or in the bowel, of turning starch into nourishing food. There is no starch in milk.* Starch is a vegetable food, and we see that nature does not mean babies to be vegetable-eaters, for vegetable foods are full of starch. If they take it and it is undigested, as is usually the case, it irritates the bowel. Thousands of babies die from this cause every year. The bowel tries to get rid of the starch which it cannot dissolve and absorb, and diarrhœa is often the result; and perhaps the baby wastes away from want of nourishment, though it may be taking quite a large amount of food. But, as we have learnt, it is *not* what we eat, but what we *absorb* of what we eat that nourishes us. Sometimes the food-tube of an infant has been found to be lined with white starch which it could neither digest nor absorb, but which

had caused its death. Some patent foods are useful when a child does not thrive on cow's milk by itself, but we must always remember that starchy ones must not be given until it is more than seven months old. Exceptional babies can sometimes digest it a little earlier than this, but milk is still the best for them and the most nourishing. Starchy foods sometimes make a baby large and fat, but it is not firm flesh, and the infant is apt to be pasty-faced and flabby and far from strong. Baked flour, arrowroot biscuits, and cornflour are starchy foods, and must *not* be given to very young babies.

Sometimes, if fresh cow's milk cannot be got, condensed milk has to be used ; and if this is the case, we must be careful to employ only one of the best brands, made from whole milk. We must read the labels and find out whether it is whole milk or skimmed milk. The sweetened milks, when watered down according to directions, are very poor food for a baby and too full of the wrong kind of sugar. They make a child rickety. The unsweetened whole milk is the only one which should be used. Some babies who cannot digest cow's milk in its ordinary form, can digest this milk, and it is useful when the fresh milk supply is bad. Babies fed on sterilised or condensed milk, as well as those fed on patent foods, are, however, apt to suffer from scurvy, from want of the citrate of lime in fresh cow's milk, and they should be given a little sweet orange- or grape-juice once or twice a week.

"Dummies," or "comforters" as they are somtimes called, should never be allowed. They are not necessary, and they are very harmful. The perpetual sucking presses the tongue against the roof of the mouth, and may alter its shape in such a way that the air-space in the nose is made smaller by the roof of the mouth being pressed up ; the jaw also is narrowed in such cases, which results in not leaving proper room for the teeth when they come. As a consequence of the narrowed air-space in the nose, the child finds it difficult to obtain enough air by that passage, and so becomes a mouth-breather. Mouth-breathers, as we have learnt before, are more apt to get colds and coughs, and to lose their teeth early. Children who breathe through their mouths during the day often breathe through their noses at night, when they are asleep. As their noses do not allow them to breathe in freely, perhaps through the nostrils having become narrowed, or possibly from the mucous membrane having thickened in consequence of the passages not being enough used, the result may be that the child does not get enough air. We know what that means. It means that the citizen cells all over the body are starved and the child cannot use its brain properly ; for the cells cannot work brightly and well without plenty of fresh air, nor can any of the body cells grow and do their work as they ought to do, and so the whole body suffers. The constant use of comforters helps to bring on this

condition. As a rule, they are dirty and dangerous things. It is dreadful to see a wet, warm dummy comforter falling on the ground, picked up, hastily wiped, perhaps on a soiled handkerchief, and thrust again into the unfortunate infant's mouth, probably covered with germs. It is often worn hanging against a soiled bib.

Feeding a child whenever it cries, and not keeping to regular hours, is a common cause of pain and indigestion; so also is wrong feeding. Starchy food often causes indigestion; so may cow's milk if the curd is too hard for the infant. In this last case, we may have to weaken the milk a little, or use half limewater for the water we are adding, especially if there is diarrhœa. But if there is constipation, we need to use barley-water or oatmeal-water.

Extract of malt is good in constipation,—the dose is half to one teaspoonful in each feed.

It sometimes happens that a baby has to be given a good patent food which has no starch in it, or only starch which has been changed to sugar. Foods such as Allenbury's and Glaxo are practically dried milk, and these can safely be given to a child not yet old enough to digest starch and who is not doing as well as it ought to on cow's milk, but it is best to let the doctor or nurse choose the patent food. Remember that new milk is best always where it is being digested, and we should not give it up for a patent food until we have tried every way to make it right for baby. If a child is sickly and delicate, it may have to be given a food that is partly digested, such as Benger's, or foods prepared with peptonising powders, such as Fairchild's Peptonising Powders; but such foods must only be used for a short time, until the child is better, and then it must be gradually accustomed to ordinary milk. If it is kept long on partly digested foods it does not develop its own powers of digestion, and there may be a great difficulty afterwards in getting it to eat and digest as it should.

If a baby has wind or colic from indigestion, we must do what we can at the time to relieve the pain, but we must not be content with only doing that, but we should use our brains and find out what caused the trouble, and then put things right. It may arise, as we have seen, from wrong food, from food given at irregular intervals, from cold food, from taking food too quickly, from too much food, from food that is too strong, or it may come from *dirty* food, or *stale* food.

To relieve the pain, we can give half a soda-mint lozenge in a teaspoonful of dill-water or peppermint-water, or we can rub the stomach with the warm hand from right to left, round and round, in the same direction as the hands of a clock, *never* the other way. If we remember our lessons on the food-tube and how the lower bowel lies in the body, we shall know the reason for not rubbing in the contrary direction.

Whatever we do, however, we must not forget to think out the cause of the pain, for we should never act as some people do who are quite content to dose the poor baby with strong waters every time, rather than take the trouble to think things out a little.

We must never give a baby soothing-syrups or sleeping-draughts. They all contain opium in some form or other, and opium is a poison. Laudanum, which is a form of opium, has been known to kill a baby when only one drop was given. Things of that sort are very bad for the brain, and they stunt growth.

When the baby has begun to cut its teeth, it may have a little starchy food. If it is being artificially fed, thoroughly baked flour can be added to the milk once or twice a day, or bread jelly can be given. After eight months it can begin to have a little more; and if at nine months it has cut some teeth, it can have bread and milk, which is very nourishing, also well-cooked milk-puddings. Other things good for it are bread crumbs soaked with gravy, the yolk of a lightly boiled egg, a little thin bread and butter, a little mashed potato and gravy; gradually also more egg can be given either in puddings or eaten alone. Broths are very good. No hard food should be given, and no such things as beer, pickles, cheese, pork, bloaters, or sausages. Meals for a child of a year old might be:—A bowl of bread and milk for breakfast; and a change can be made every now and then by its having a lightly boiled egg, or well-made, strained porridge, and bread and butter. In the middle of the morning it should have a drink of milk. At dinner, boiled fish without bones is very good for it, and so is broth; or, instead of the fish or broth, a very little pounded-up meat. Soft and well mashed-up potatoes, or greens, also well mashed, and a little gravy, are good, and the child can also have a little rice or other milk-pudding. At tea it might have bread and butter and a mugful of milk to drink, and a little milk later on if it is hungry.

We should always know how to make good beef-tea, so we will learn how to do it; but, at the same time, we will remember that as a food it is far inferior to milk. The nourishing part of meat is largely the particular body-building food which resembles the nourishing part of white of egg. We know that when we put white of egg into boiling water we make it hard. The body-building part of meat is of the same nature as the nitrogenous food material *albumen* in white of egg. Therefore if we boil meat we harden the nourishing part. We want to get that nourishing part *out* of the meat when we make beef-tea, not to harden it and shut it up inside the meat. Neither do we need to get all the gelatine out, which sets firm when the tea is cold. The best gravy beef is free from the bone and gristle that forms jelly. Some people think that beef-tea is only nourishing when it sets firm,

but as a matter of fact jelly has no nourishing power by itself. Good beef-tea is nourishing and appetising, but it should not be given where there is any tendency to diarrhœa, which it may increase. Beef-tea, properly made, helps people to benefit more by any other food which they may be taking.

A young child under a year and a half old needs five meals a day. Breakfast about eight o'clock; and in the middle of the morning a drink of milk and a biscuit; dinner should be about noon; and then comes tea, and a drink of milk at night. At two years of age four meals are enough. It can quite well have well-made oatmeal-porridge for breakfast, with milk or treacle to eat with it, and milk to drink. Bread and bacon-fat are very good for it, for the bacon-fat is very digestible, and all young children need plenty of fat in some form or other, whether in the shape of butter, or margarine, or well-cooked suet, or some other easily digestible form. At dinner it can have finely minced meat or fish, and milk pudding, and milk to drink. Hard crusts may now be given, and are good exercise for the teeth, as we learnt before in another lesson. Milk, water, or later on cocoa, are the only suitable drinks for young children. Some mothers give their young children tea, because they say that the children cry for it and will not take milk: that is because the mother has accustomed them to expect it, and they miss the warmth of it. It is better to add a little plain hot water, or to warm the milk, for tea is a stimulant, and no stimulants are needed or good for young children. Terrible harm is done by giving young children sips of beer, and even spirits. It seems almost impossible to realise that women can be so ignorant and wicked as to give babies strong drink; but, unfortunately, it is sometimes the case that children in hospitals have been found to be ruined in health and strength for life by having had both gin and whisky.

One more thing we must bear in mind, and that is, that though we may know a good deal about the care of babies, yet when they are ill we must never neglect to send for the doctor. Sometimes he is only sent for when it is too late.

Blackboard Summary.

1. The best and safest thing for a baby is to be nursed by its own mother.
2. Wrong feeding, dirt, and cold kill babies.
3. If a baby cannot be nursed by its own mother, then the next best thing for it is to have good cow's milk, which should always be scalded, covered, and kept in a clean jug or basin in a cool, clean place.

4. Long-tubed bottles are death-traps for babies. Use round or boat-shaped ones, with a teat only, not with a tube.

5. Bottles must be perfectly sweet and clean and be kept in cold water between feeds.

6. Any food left in the bottle must be thrown away and *not* kept till the next feed.

7. Babies must be fed regularly. "Feed the baby by the clock not by the cry."

8. Starchy food is poison for young babies. Up to seven months they should have nothing but milk, and up to nine months very little else.

9. We should be ashamed to give our babies what we take ourselves. It shows our ignorance.

10. Baby must not be jogged up and down just after it has had its food; it is not a churn.

11. "Comforters" are dirty things, and do babies much harm.

12. Soothing-syrups and teething-powders are bad for babies.

13. If baby is ill, *send for the doctor*.

RECIPES.

RECIPE FOR BARLEY-WATER.

Two teaspoonfuls of Robinson's prepared barley in a pint (two tumblerfuls) of water. Simmer for a quarter of an hour, strain; keep covered, and make fresh every day.

ANOTHER METHOD.

Wash a tablespoonful of pearl barley well in cold water; strain, add one and a half pints of cold water, and boil for about twenty minutes till it is only a pint. Strain, cover, keep in a cool place, and make fresh every day.

RECIPE FOR LIMEWATER.

Get from a builder's yard a lump of freshly burnt lime as big as an egg; slake it by *sprinkling* cold water on it. Put the crumbled lime into a quart bottle and fill with clean, cold, boiled water; shake it well, and let it stand for twenty-four hours. Keep it well corked, for air spoils it. When using it, do not shake the bottle, but pour off from the clear part at the top,—there will be lime left at the bottom, and as long as this is the case, keep on adding water to keep the bottle full. Make fresh about every three weeks.

RECIPE FOR OATMEAL-WATER WITH MILK.

Boil a teaspoonful of fine oatmeal in a quarter pint of water, with a little salt, for a quarter of an hour; strain, and mix with half as much boiled milk, and a lump of white sugar. This is to be given instead of their usual feed to babies who are very costive.

RECIPE FOR BEEF-TEA

Take 1 lb. of gravy-beef and shred or cut it up very fine. Place it in a stone jar with a pint of cold water and a teaspoonful of salt; let it stand for an hour; stir it every now and then. The cold water draws out the good. Cover and place in a covered saucepan containing a pint of boiling water; keep the water boiling for as ong as five hours if possible round the beef-tea jar, adding more water when necessary; the water inside the jar will always be below boiling-point. Strain, set aside to cool, and then remove the fat. If the jar is put in the oven, it must be a warm not a hot one, and half a pint more water must be put in to allow for evaporation. When beef-tea is made in this way, without allowing it ever to be boiled, all the good is taken out of the meat.

CHAPTER XLIII.

GENERAL MANAGEMENT.

Necessary Apparatus.

Banana-crate, untrimmed.
Trimming for the same.
Mattress filled with bran or chaff.
Mackintosh or other protective sheet.
Soft blanket.
More expensive kinds of cots, etc., if desirable.
Bean or other plants, variously treated.

Note.—In winter-time it may be best to start the little plants by growing them on a tray of earth, when they will grow rapidly if bottom heat be given. When well started they should be planted out.

We have learnt in other lessons about the wonderful way that the citizen cells in our brains have developed their power of answering to a stimulus, and we remember that they are all there at birth, and are never renewed. But the brain cells of an infant newly born are not yet developed, except those in the lower parts. We remember that the acts of breathing and the beating of the heart are carried out by the work of cells in the Spinal Bulb, but that the power to control the movements of the limbs is carried on higher up, largely in the Little Brain, and that thought and reason and judgment belong to the highest centres of all in the Big Brain. Now a tiny baby breathes and cries, its heart beats, it moves its limbs, its skin and other organs act, all its mere life goes on well, and it can suck from the very first, but the brain as a whole is not developed. At first an infant can neither hear nor see properly. It cannot "take notice" of what is around it, for the brain is not yet ready, and for its proper development it wants proper treatment.

A young baby needs regular sleep and plenty of it, if it is to develop as it should do, for an infant's brain grows at an extraordinary rate. During the first three months of life it will increase one-third of the whole of its growth. The second third is added by the time it is about two and a half years old, and the third by about seven to eight years of age. Both brain and nerves will suffer if the child does not get enough

sleep, and a new-born baby ought to sleep about twenty hours out of the twenty-four.

Babies should not sleep in the same bed as their mothers at night, for many babies die every year from this reason. The helpless little thing may get its face pressed so hard against its mother that it cannot breathe, or perhaps the mother is very tired and turns over, partly on to the baby, who is smothered. Sometimes, sad to say, the mother has gone to bed far from sober, and this has happened as a result. Even if nothing worse occurs, a baby is low down in the bed, under the clothes, and gets bad air to breathe. Babies ought always to sleep in a separate cot by the mother or nurse's bedside. It is very easy to make a cot, if we happen not to be able to buy one easily. The baby is just as happy in a clothes-basket or a banana-crate, or an orange- or egg-box, as it would be in a cradle made of gold and tortoise-shell.

Here we have a banana-crate turned into a cradle, and a very nice one it makes. Some people think that it is safer and cleaner if the wood is just smoothed and polished, and the cradle not trimmed at all. It looks rather bare, however; and if we tie the coverings on, and make them of stuff that is easily washed and boiled, and kept very clean, it certainly looks much prettier. We have here both an empty, untrimmed crate and a trimmed one. This trimmed one is first covered with unbleached calico. The calico has tapes sewn on to it which fasten on to the crate and can be undone in a minute. A pretty flounce of muslin goes round the top and hides most of the calico. It also is fastened by tapes, and comes off at once. The mattress can be made of two yards of unbleached calico, filled with bran or chaff, as this one; the stuffing can often be changed. A mackintosh sheet should be put over the mattress. When people cannot afford a mackintosh, they can get a piece of the waterproof paper that is sometimes put on damp walls; this can be burnt often and a fresh piece put on, as it is cheap. Brown paper will do, but must also be frequently burnt. If bits of old blankets are used to protect the mattress, they are often allowed to get very smelly and nasty, from being often wetted and only dried and put back. The infant's bed *must* be kept clean and sweet.

A tiny baby is simply rolled in a very soft blanket and put gently on its side into its cot; and remember not to let it lie always on the same side. After being fed we must be sure that a baby is on its side, for it is apt to choke if it is sick and lying on its back. The cot should be shaded from the light, and if flies are about, a piece of coarse muslin should be thrown over it to protect the baby, for as we know, flies go to dirty places, and we do not want to allow them to carry their dirt and germs to the baby. Notice if the child sleeps with

its mouth open, and if so, close it gently, and thus teach it to breathe through its nose. We remember from our other lessons how important this is.

A baby can be accustomed from the first to be put into its cot, without hushing to sleep or rocking. It may lie awake and cry a little at first, but it soon gets accustomed to it if it is warm and comfortable, and knows it does not get taken up if it does cry.

Let there be plenty of fresh air. If the weather is cold, and the baby is sleeping alone, a hot bottle, properly covered up, can be put into its cot. If we have not got the rather expensive rubber one, then a stone ginger-beer bottle in a little flannel bag will do quite well, if it is well corked up. A baby has great need of warmth, for it loses heat quicker than a grown person; but warmth must not mean stuffiness or over-coddling.

When the infant is older it naturally takes less sleep, but it must still have a great deal. When it is about three months old it should be sleeping twelve hours at night, and have two good long sleeps in the day. Later on, one day-sleep will be enough, but it should be about two hours long. It is good for children to have a day-sleep up to about five or seven years old, and no little child should be allowed to sit up late. Late hours are very bad for the growing brain and body.

When we carry a baby we, in this country, usually carry it on the left arm, so as to have the right hand free to use for anything we have to do. We can also protect the child better that way. Inexperienced people often do not carry a baby comfortably. The child's head lies on their arm, but there is an unsupported part between the head and back, or else the head lies too far over the arm in a very uncomfortable way. The reason is that they have not yet found out that in carrying a baby flat, the left shoulder should be brought as far forward as possible; and by doing so the child's neck and back, as well as its head, are lying comfortably supported on the forearm. Always support the back and head of a young baby as you lift it about, and never prop it up before nature gives it the wish to try and sit up by itself. Mailcarts, in which the baby is propped up, are very bad for it before it is about five months old; and even then it should not sit up for long at a time, and the back should be well supported and its legs kept very warm. A baby out for an airing and lying down should have its eyes shaded; it is very trying to lie staring up at the bright sky with no shade at all.

In wheeling a mailcart or a perambulator, we must take care not to bump the child about when wheeling it from or on to a pavement; and if we stop the perambulator on a slope, we must be careful to place it so that it cannot start to run down-hill. Several accidents

have happened from not being careful about this. A baby ought to go out every day,—we have learnt so much about the value of fresh air and sunshine that we quite understand why this is so. We do not want to coddle a child and make it like a hothouse plant. If there is a garden, it is very good to let the baby sleep out of doors in its perambulator. The hood can be let down, and the baby will come to no harm even in a slight drizzle, provided the place is sheltered from the wind. Even when the weather is no longer either warm or sunny, a baby accustomed to the fresh air can sleep out quite well, if it is well wrapped up and kept warm.

Indoors we must always take care to keep the air fresh and pure and not be afraid of open windows. Never stuff up the chimneys or close the registers of the grates.

The exercise of its limbs is very good for a baby, it helps the growth of both brain and body. But it is not good exercise to lift a baby by its hands and swing it about. We might injure its delicate bones or dislocate the joint of the shoulder. Tossing about and rough romping often lead to accidents. Baby should be given plenty of opportunity to move its limbs, and it will love to stretch and kick about after its bath. As it gets older it will want to crawl. We must see that the floor it crawls on is clean, and it is a good plan to keep a rug or blanket to spread on the floor for it to be on. A baby that has begun to crawl will soon begin to hold on to things and try to pull itself up, and it may begin to try and walk at about ten months old, but sometimes not for a good while later. If it is a heavy baby, or one that is not strong, or possibly inclined to rickets, it should be kept off its feet as long as possible, or it may get bandy legs.

The law compels people to have their children vaccinated, unless, before the baby is three months old, they have obtained a certificate saying that they have a conscientious objection to vaccination. Generally the doctor vaccinates on the arm, and he does it with vaccine-lymph, obtained straight from the calf, and very carefully prepared, so that no harmful germs can be present. We must be careful to see that a baby's arm is properly protected afterwards. Very often, with careless people, dirt and germs get in through the tiny scratches on the skin, and then there may be much inflammation and trouble. Vaccination shields can be bought from the chemist; but after they have been used they should be destroyed. We should never borrow one from another person; it may be far from pure, and may give baby a bad arm. The arm must be protected from the rubbing of the clothes, and from dust and dirt, by a new clean shield, or a piece of clean cotton or linen. The place of the vaccination must not be washed, for fear of washing off the vaccine, but the limb can be

washed all round the part. If blebs form, as they will if the vaccination "takes" properly, they must not be interfered with in any way, but kept perfectly dry, and be powdered with boracic acid powder, and then covered with a little clean, absorbent cotton-wool.

FIG. 110.—Sickly and yellow; grown in the dark and airless cupboard. A child living in dark, unhealthy rooms in a dark street.

Cleanliness, fresh air, sunshine, and exercise are golden rules for a baby. Children are like plants, they can be well grown or badly grown, and good care will often make a delicate child strong. Here are some plants.[1] I grew them all alike, and they were all sturdy and strong. We will imagine that they are children. One or two of them I put away in a dark place, a cupboard without air or light. What is the result? Our strong, green plants have become sickly and yellow. One of them had a little crack of light close to it under the door, and it has grown a long pale stem towards the light (see fig. 110). These pale, sickly plants are like the children who have been brought up in dark rooms and dark courts and alleys, without their proper share of sunshine and light.

FIG. 111.—Poor soil. Wrong or insufficient food.

Here is another plant; it looks very miserable; we put it into sandy soil with scarcely any good earth in it (see fig. 111). It is like a baby brought up on wrong food: it has plenty of soil, just as the baby has plenty of food, only the soil does not contain proper nourishment. Starchy foods are like that for a baby. Here is another plant. How tall and thin and delicate it has grown! It was brought up in a hothouse, and seems to have got very delicate, for it was put out in the cold and began to droop at once (see fig. 112). It is like a coddled child who catches cold easily. This one, again, is nearly dead. Poor thing, it never had enough water or attention of any kind. It is like a badly neglected child. It was in a very dusty place, and it cannot breathe

[1] These plants should have been shown to the class when in the first stage of healthy growth, and be put away in the various places with the knowledge of the pupils.

properly, for its leaves, which are the lungs of a plant, are covered with dust and dirt, and the little mouths or openings on the leaves through which it breathes are all choked up (see fig. 113). Here is another plant; what is it like? Very strong and sturdy, and green and well (see fig. 114). It was brought up in the open air, and had plenty of good soil, sunshine, and water. It is like a healthily brought-up child, not pampered, or coddled, or wrongly fed, but treated wisely and simply.

FIG. 112. — Hothouse grown. Delicate and "coddled."

It is not only babies, but all children, who require to be sensibly dressed. Neck, arms, and legs should be covered. We have learnt before about clothes, and how we ought to cover the body evenly, with warm absorbent material, and not cramp its growth in any way by wearing tight things. Clothes that are too tight across the chest cramp the lungs, and tight boots and shoes deform the feet and give chilblains, because they hinder the circulation.

In looking after babies, we must be quick to notice when they are out of sorts. It is easy enough to see when a baby is really well. It does not always mean health if it is large. Some babies are very fat,

FIG. 113.—Neglected and starved.

FIG. 114.—Strong and healthy, grown in good conditions. A healthy child properly brought up.

from eating too much starchy food; and we know that fat is not flesh. They are often pale and pasty, with a curious transparent, waxy

look about the skin. They have not the pink, firm, rosebud face that a healthy baby has. The healthy child gains steadily in weight every week, and it is an excellent plan to weigh a little baby from birth, and see that it gains properly. If it does not gain, then something is wrong, and we must use our brains to find out what that something is. A baby loses weight for the first two or three days after it is born; but that is natural, for Nature makes it come into the world with a store of reserve food to draw upon, and it can quite well live on that, and needs only very little else besides being kept warm. Sometimes, if the mother cannot attend to the baby herself, ignorant people give it all sorts of messes, and sometimes do it a good deal of harm.

A healthy baby should put on four to five ounces a week, and some babies will put on half a pound or even more. But the principal thing to look for is a steady increase, even if it vary week by week. At birth it may weigh seven pounds; but some babies weigh less and some more. At five months old it ought to have doubled its weight, and at eighteen months it should have trebled it. The average gain, for the first year, is a pound a month. A baby measures about nineteen inches when it is born, and it should be double that when it is four months old. It is best to weigh a baby after its bath. We should keep a warm wrap for it when we put it in the scales, and know how much the wrap weighs, and allow for that.

Blackboard Summary.

1. A tiny baby ought to sleep about eighteen to twenty hours out of the twenty-four. It should have a separate cot, and be kept quiet, clean, and warm, but allowed plenty of fresh air. Older children should have two or three long sleeps in the day, and sleep twelve hours at night.
2. A child's brain and nerves cannot grow properly without plenty of sleep, and late hours are very bad for all children.
3. A baby's back and head should always be well supported when lifted and carried, and it must not be propped up until it can sit up of its own accord, and then it must be well supported.
4. Let the baby go out every day, if possible, and also sleep out of doors in the daytime in the garden, well wrapped up.
5. Cleanliness in food, in body, in clothes, and in everything round it, with fresh air, warmth, exercise, sunshine, good food, and proper sleep, are the golden rules for a baby.
6. The baby should be weighed every week, and if it does not gain, we must use our brains and find out why.

CHAPTER XLIV.

GENERAL MANAGEMENT—*continued.*

Necessary Apparatus.

Materials for making whey.
Materials for making albumen-water.
Materials for making fresh, raw meat-juice.
Long bone softened in hydrochloric acid, as in the lesson on the skeleton.

We have been talking about how to keep a baby healthy, but to-day we must think about what to do if a baby should fall ill. Little simple ailments are often quite rightly treated at home; but if a child is really ill, the doctor should be sent for at once. A little child may slip through our hands from want of doing this. Thousands of children die every year from wasting diseases. If they are born unhealthy, of unhealthy parents, it may be that some of these children owe their deaths to this fact; but most children are born healthy, and of those who die many are made unhealthy in the first few weeks of life, by the ignorance of their mothers. It is wonderful to think of the loving work of good mothers, and all we owe to the mothers who have brought us up and sacrificed so much for us, but it must not make us shut our eyes to the fact of those thousands of children dying every year because of bad bringing-up. Sometimes the mother is so poor, from no fault of her own, that she cannot afford proper food for her child, and is too delicate to nurse it herself; but we are not talking of these, but of the really careless and selfish ones, who do not trouble to do better even if they are taught.

Very many young mothers lose their first children from want of a little common-sense knowledge, and when the baby is ill they take advice from people who perhaps are not very wise themselves. That is why we need to learn something about the management of babies at school, so that we may have some idea of the most important facts and the reasons for doing certain things and not doing others.

Diarrhœa is one of the commonest ailments for young babies, among those who are hand-fed; it is responsible for three-quarters of the total registered deaths in England and Wales of babies under a

year old: it attacks children under five also. It is worst in towns. It is not only the sickly babies that are attacked, but the healthy ones suffer as well. It is at its worst during the hot months of the year—July, August, and September. Its first and principal cause is DIRT. Where the people of a place have neglected cleanliness, there Infantile Diarrhœa flourishes. Dirty streets, collections of horse manure in stables and yards, breeding thousands of flies, together with bad drainage and bad milk supply, all mean Infantile Diarrhœa, especially in hot weather. Flies carry the germs which cause diarrhœa; but it is *dirt* which breeds the flies. We have been learning in our lessons what an important thing it is to get rid of dirt in our homes, and not let waste matter lie about for flies to breed in. Wherever there is filthy matter, there flies can swarm on it and lay their eggs. Maggots hatch out, and in about a fortnight become flies; these flies wander from place to place, and they have sucker-like feet, which take up bits of what they walk on, and also harmful germs, and carry them to the next place (fig. 115). A fly may walk over some disgusting dirt, and then come into the house, and perhaps fall into the baby's milk if it has been left uncovered, or settle on the infant's face. There is no doubt that they carry the disease of diarrhœa in this way, by walking over food (fig. 116). Dr Nash, Medical Officer of Health for Southend, showed that the deaths from summer diarrhœa had been much the same for some years in July, August, and September, till one year when there were no flies in July and August, and then *there were no deaths.* During the first fortnight in September the flies began, *and so did the diarrhœa.* Thirteen babies died that fortnight; then the flies went, and *the diarrhœa went too.* We must keep our houses and backyards very clean. We must keep flies away from food. We must burn all waste food-scraps in the kitchen fire, as we learnt in our other lessons. We must be sure to boil the milk for baby, and keep it in the cleanest possible way. It is no uncommon thing in dirty houses to see the

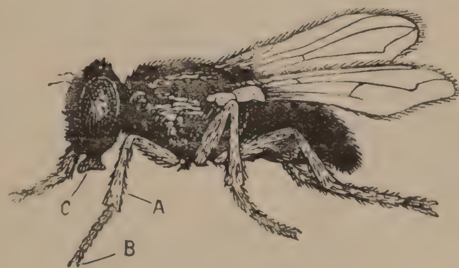
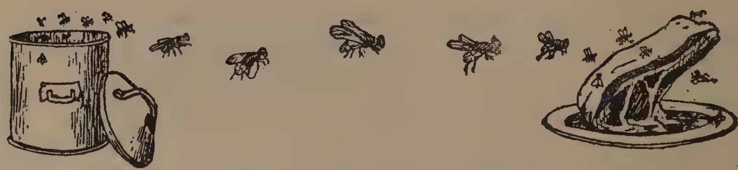


FIG. 115.—The House Fly (magnified).

A, The legs covered with bristly hairs to which germs and filth cling.
B, The glue pads on the feet, which are capable of carrying thousands of disease germs.
C, The trunk through which the fly sucks up filth, and vomits it back on our food.

baby's milk kept in a dirty jar, with flies drowning in it. It has been noticed too that sometimes the smell of the feeding-bottles given to the unfortunate babies in such houses is sickening. The wrong kind of bottle is used, sometimes with a long tube, and neither the one or the other is clean. The bottle has not been thoroughly cleansed, and a film of sour milk clings to the sides; and not only milk that is sour,

From the consumptive's spittoon to the baby's milk.



From the dustbin to the dinner-table.

From the manure-heap to the milk-jug.

Fig. 116.—How Food is polluted by Flies.

but milk that is *putrid* and holds millions of germs, which are going to get into the baby's stomach and bowels in the next feed, *to give it the deadly poison of diarrhœa.* There is no doubt that sometimes the milk given to babies in dirty, careless households is simply swarming with evil germs, and is, as Dr Newman has said, "little short of rank poison to an infant."

Flies, germs, and dirt all go together, but it is *dirt* that brings the other two. Epidemic Diarrhœa, or Summer Diarrhœa, is therefore a preventable disease, and is due to *dirt*,—*dirt* in the soil, *dirt* in the

streets, *dirt* in the drains, *dirt* in the backyards, *dirt* in the houses, *dirt* on the child, *dirt* on the mother, *dirt* in the air, *dirt* in the food, and *dirt* on that *dirty* thing a "comforter" hanging round a child's neck against a *dirty* bib, or dropped in *dirt* and picked up and wiped on a *dirty* handkerchief or other *dirty* thing, and thrust back into the mouth of an unfortunate baby.

In diarrhœa, especially the epidemic kind, the doctor ought to be sent for. Mild attacks of diarrhœa are often due to chill, which makes a child less able to resist any germs which may be present, and it may be feverish and perhaps sick. If the mother is nursing it herself, the attack will probably pass off with warmth and care; but if the baby is bottle-fed, it is not so easy to get it well.

In *Epidemic Diarrhœa*, which is infectious, the child is very ill. We must lose no time in sending for the doctor, and we must obey his orders *strictly*. The dirty napkins must be put at once into cold water and disinfectant and covered over, and then boiled afterwards. Every vessel must be scalded out well, and we must wash and disinfect our hands after attending to baby, using Jeye's Fluid, or Cyllin, or some other good disinfectant. The baby must be kept quiet, clean, and warm. If the doctor says, "give no food," we must *obey* him; for he wants to rest the injured and inflamed bowel, and get rid of the germs and poison. He will probably order warm, boiled water to be given to flush out the bowel, and later he may order albumen-water.

If a baby has *convulsions*, send for the doctor at once. They are often caused by starchy food being given too early. Loosen all tight clothing, let there be plenty of air, place the child in a bath of warm water up to its neck, and put cold water with a sponge or handkerchief on its head. After it has been in the warm bath about three minutes, it should be taken out and wrapped in a warm blanket and held on the nurse's knees, with its feet kept very warm, and cloths wrung out of the coldest water possible put on its head, and changed as soon as they get warm, which may be at once. The rule is to keep the feet warm and the head cool. As it is very possibly food irritating the bowel which is causing the mischief, a dose of castor-oil will probably have to be given.

We have already spoken about constipation and wind, and how to prevent baby from getting chafed by taking care about changing its napkins and keeping it clean and dry, and using a simple ointment such as zinc ointment, or one made of zinc and vaseline mixed. No soda should be used in washing the napkins. It is only by being careful and washing the baby when its napkins are changed, and using vaseline or some other ointment, that we can prevent it from getting chafed and being made very miserable and unhappy. It is easy to see if a baby is

ill. A healthy baby passes its motions about three or four times a day when it is very young; after six months it passes them about twice a day. They should be yellow and pasty, like mustard, and there should be no white curd in them. If there is, it shows that the milk is not being digested properly. If the motions are watery and green, we should send for the doctor, as there is a danger of diarrhœa. If they are very hard, the baby is constipated, and olive-oil or cream will have to be added to the food. A baby who is out of sorts is apt to be fretful and cries; it does not know what it wants. It may seem to long for food, and yet be sick after it, or it may refuse its food. It may be hot and feverish, and its skin may feel burning and dry. In that case it must be kept warm in its cot and the doctor should see it. He should also see it if it has a cough. We must be careful not to think that we can always doctor a baby safely ourselves. It is quite true that a little feverishness may yield to a little fluid magnesia, or to keeping the baby warm and quiet, but it must never be forgotten that in any doubt the doctor should be sent for—he is often sent for when it is too late.

Red-gum rash. This is not at all a serious trouble. Tiny rough red pimples may come out on the body. They are due to a little acidity of the stomach or overheating. The rash usually goes away of itself, but if it is troublesome, then a dose or two of fluid magnesia or limewater (a teaspoonful of either) will help it to go.

Sore eyes. Sore eyes may be due to a draught. We keep the baby out of the draught, and bathe the eyes with a clean soft rag and a little warm, weak boracic lotion, and burn the rag. If it does not get better or any "matter" forms, a doctor must be seen at once about it. A child's eyes must never be wiped with the handkerchief or apron. Clean things only must be used. Careless and ignorant people have been seen to pick up the hem of their petticoat, polluted with the dirt of the street, and wipe the eyes of their young babies with it. It is sad to think of the harm that is done by the slovenliness and ignorance of people who might know better.

Rickets. "He will grow out of it." How often do we hear these words said about a rickety child. *He ought never to have grown into it.* What causes rickets? Usually WRONG FEEDING, or poor digestion. Nearly all rickets can be traced to faults in feeding, leading to an upset liver and poisoned nervous system.

Feeding children too early or too much on such things as biscuits, potatoes, bread and butter, cornflour, sopped bread with very little milk, may cause rickets. Condensed milk, if used too long, sometimes causes rickets. Condensed milks are too poor in fats when watered down, and the sweetened ones are too full of sugar. The cheaper kinds are poor in everything. Patent foods also are poor in fat, and they

have not got the fresh citrate of lime present in cow's milk, which prevents scurvy. If they or preserved milks are used, then a little sweet fruit-juice should be given or a little fresh meat-juice.

Even if the mother is nursing her child herself it may sometimes get rickety,—the mother may be delicate or not getting properly fed. A nursing mother should have good, plain, nourishing food, and as a rule no stimulants in the shape of beer or spirits.

Giving starch with food which is rich enough in fat and proteids sometimes upsets the digestion so much that the good in the food is not digested properly. We must always watch hand-fed babies carefully for the very first signs of rickets, for it is a thing which comes on very quietly, like a thief stealing in. For that reason, it is usually seen first in older babies and young children, though the mischief may have been going on for some time. Even young animals, brought up at the Zoological Gardens in London, have been found suffering from rickets, because they were getting too little fat. They had to give the baby bears milk and cod-liver oil, and then they recovered.

How do rickets begin to show themselves? If a child is restless at night, throws the bedclothes off, and perspires a great deal about the head, we suspect the beginning of rickets. Advanced rickets shows many signs. The child has too large a stomach, and the front opening in the head (the anterior fontanelle) does not close up as it ought to do. The head of a rickety child has plainly marked lines across it, where the bones meet. It is called the "hot cross bun" head. In these advanced cases the chest may be deformed and be like a pigeon's breast. The ribs form lumps of bone along them like beads, and this symptom is known by the name of "rickety rosary." The joints get large and thick, and the shafts of the long bones bend and get curved, particularly the leg bones if the child is walking. The citizen cells of the bones cannot do their work properly, for they are not getting the right materials brought to them in the blood. They are like workmen building a house and starved from want of proper food to such an extent that they cannot lay the bricks as they should do. The bone cells cannot use the lime salts properly or store them evenly. They try to make up for it by building as quickly as they can and all anyhow, so the joints which are special centres of building get overgrown with badly made bone. The effects are very harmful, for the deformed ribs and breastbone press on and cramp the lungs and prevent them developing as they should. This may lead to consumption in later life, besides tending to make the person delicate in other ways, for we know how dependent the body cells are on the lungs for their supply of fresh air. The bones overgrow at some places and actually soften at others. In health, as we learnt, bones have more mineral matter than animal

matter. Do you remember what a bone was like after we had dissolved out the mineral salts? Yes, quite soft. Here is a specimen again. That softness shows how the bones in a rickety child can become crooked; for, in bad cases, bones which had been hard, get soft, the lime salts having been absorbed or dissolved out. A rickety bone may have far more animal matter than mineral matter.[1]

Besides the alterations in the bones, serious changes may take place in the organs, particularly in the blood-making one called the spleen. It is sometimes enormously enlarged. There is irritation (catarrh) of the lungs, stomach, and bowels, so that rickety children are peculiarly liable to die from bronchitis, pneumonia (inflammation of the lungs) and from all wasting diseases (marasmus, infantile diarrhœa, "consumption of the bowels," etc.). Rickets is indirectly one of the common causes of death under five years old, for a child who dies from bronchitis would very likely not have died if it had not been rickety, and so with other diseases. A child who is not rickety may also die of them, but it is mostly the rickety children who die when attacked.

It is dreadful to think that of the children under three years old brought into hospital, *nearly half show signs of rickets.*

A rickety child should be put under the doctor's care and his advice followed. It should not be "coddled" by being overclothed, and it should have as much fresh air as possible. We can use a window-board in bad weather, and in fine weather we can have the windows wide open. We must have fresh air day and night. We should examine and think over the food, and see that the child is fed as the doctor orders. It may have to be given raw meat-juice and cream.

Older children should be sensibly fed, and not allowed to eat too much starchy food, instead of milk and eggs. A baby should eat animal food,—milk is an animal food, and older children should also have plenty of it. A child of two or three years old can take a quart of milk a day. Cod-liver oil has often to be given. The milk gives all the lime salts that the child is likely to need without the necessity of giving any more. With sunshine, baths, proper clothing, and proper food, it is wonderful how soon a rickety child will become rosy and straight and well.

One of the worst effects of rickets is shown in the teething. When a baby is born, it has the first teeth in its jaw waiting to be hardened by lime salts and grow out (see fig. 51, p. 92). Underneath are the beginnings of the second set. If the child is being fed on wrong food,

[1] In health the proportions should be about 37 per cent. organic and about 63 per cent. inorganic matter. In rickets there may be as much as 79 per cent. organic and only 21 per cent. inorganic.

which does not nourish it properly, then the teeth cells cannot fix the hard mineral salts as they ought to do, and the teeth come slowly and are often badly shaped and soft, and therefore decay early, which is bad for the shape of the jaws and for the second teeth waiting underneath. *The early loss of the second teeth, and the misery and pain of toothache, is often due to wrong feeding in babyhood.*

Other troubles arising from rickets are bandy legs; and in girls there may be other deformities which may prove serious for them in after-life. In any case, however, there is no need to have rickets, and therefore they should be *prevented*; for in this trouble as in others the truth is again evident, that "Prevention is better than Cure."

Blackboard Summary.

1. Summer diarrhœa is a disease *caused* by dirt and *carried* by flies.
2. Dirt in the food means death to the baby.
3. In convulsions, send for the doctor. Keep the child's feet warm and its head cool and give opening medicine.
4. Never wipe a baby's eyes with anything dirty.
5. Good milk, extra cream, or cod-liver oil, with cleanliness, fresh air, and sunshine prevent rickets to a large extent.

USEFUL RECIPES.

Recipe for Whey.

Make a pint of milk just warm (be careful that it is *not* hot); add from one to two teaspoonfuls of Benger's Artificial Rennet. Leave in a warm place till the curds have separated from the whey. Break up the curd finely and strain the whey through muslin. Scald to destroy the rennet, and cool quickly.

Albumen-Water

To half a pint of cold water add the white of a raw, fresh egg, a little pinch of salt, and a teaspoonful of brandy. Shake all up well together. Give by doctor's orders.

Recipe for Fresh Meat-Juice.

Finely mince or pound up ¼ lb. of lean beef. Put on it two tablespoonfuls of cold water, stir it all well together, and let it stand in a cool place for about an hour. Put the meat into a clean piece of muslin, and squeeze out all the juice. In warm weather, make twice a day, as it does not keep well.

CHAPTER XLV.

MINDING BABY.

Necessary Apparatus.

Strips of lint or clean, soft rag.

Sweet vegetable oil of some kind, such as olive-oil, linseed-oil, almond-oil (not oil of almonds), Carron-oil (a mixture of half linseed-oil and half limewater), or use vaseline, or in some cases zinc and boracic ointment mixed.

Sponge. To show how to wring out a sponge for breathing through to relieve the distress and danger when the throat is scalded inside, put a clean towel in a basin and lay the sponge in the middle; pour boiling water over and turn the ends of the towel in opposite directions, until every drop of water is wrung out. Use the drier ends of the towel to wrap round the wet and scalding part as the screw gets tighter; this enables you to put your hands close up to the sponge and get it very well compressed. You can use a roller towel and two sticks, but it is rather large and thick for so small an object as a sponge.

Bandages.

Mustard and water. Mix in the proportion of a dessert-spoonful to cupful of warm water.

Salt and water. This is often not given strong enough in a serious case. It should be very briny.

Boracic lotion, for showing how to wash out an eye. Apparatus for First Aid in case of broken limbs or cuts.

It is not only mothers or nurses who have to mind babies, but many and many a baby is left in the charge of its elder sister; and very patient and good the elder sisters are. It is no easy task to look after a baby, especially when it is awake, and perhaps fretful, or old enough to crawl or totter about. First and foremost, we must always remember that there must be a fireguard on the fire. The law compels it. Many babies have been terribly burnt, and have lost their lives, or have been crippled and disfigured for life, by going too near a grate or range.

Especially dangerous is it for a baby to wear flannelette, particularly the cheap, highly inflammable kind which a spark will set ablaze. We must always guard against fire, and never leave matches about where a young child can get at them. A child may poison itself by sucking

the heads, or it may set itself on fire by striking the matches for fun. If the clothing of a child or that of any grown person catches fire, that person must *not* stand up. Fire burns *upwards*. Supposing the hem of the dress or the front of the pinafore is ablaze, and the child or person runs about screaming, which is what they usually do, what happens? The flames rush up higher and burn all round the chest and head, and the hot air is drawn also into the lungs. If it is a tiny flame, we can perhaps put it out at once by simply seizing the dress and crushing it together; but in more serious cases the thing to do is to put the person on the ground *at once*, and snatch up a woollen thing, a rug or woollen tablecloth, wrap it round the person, and smother the flames. If we have nothing handy, we can roll the child over on to the burning part and so smother the flames in that way. If we should catch fire ourselves, we must at once lie down and roll on to the flames while we call for help.

Send for the doctor at once. If it is a case of a bad burn or scald, the clothes may be sticking to the skin. *Do not pull them off.* Cut round them with the scissors and leave the burnt part alone. If the doctor does not come at once (and we may have to send a long way for him in the country), then we must do all we can to keep the air out and to lessen the pain. Sweet oil is best to use. Soak pieces of old, clean, soft linen or rag in oil; any clean soothing oil will do. Use olive-oil, linseed-oil, almond-oil, castor-oil, cod-liver oil, vaseline, or even fresh butter, or lard, or margarine if there is no salt in it. Put the oily strips of rag over the burnt places, and let each strip lap over the one before till all the part is covered. Then put on a soft, thick pad of cotton-wool. If you have not got cotton-wool, then use some soft, thick, woolly material to keep the air out, and cover all up gently with a loose bandage. If the injury is to an arm or leg, keep the part up, supported by a pillow. The child will be suffering from the shock to the nerves, and will very likely be cold and shivering, and very pale and faint. It should lie down, be wrapped up *very* warmly, and be given a hot drink.

A good ointment to use for burns is zinc and boracic mixed. A mixture of half linseed-oil and half limewater is kept handy at places where accidents by burns or scalds often happen, as at certain works. This mixture is called Carron-oil, because it was first used at the Carron Works.

For a slight burn or scald, we can make a strong solution of soda, and dip rags in it, and lay them on the burnt place if the skin is not broken. If it is broken, use ointment.

Some people put treacle on a burn. Treacle is a very messy remedy, but it can be used if nothing better can be got, for it keeps the air

out, which is the important thing. Flour, dusted on, is also a quick household remedy, and is cooling and soothing; but oil is best when it can be got.

Burns or scalds about the throat are dangerous. A child ought never to be able to get at the boiling kettle. Not only may it try to drink from the kettle and so scald its throat, but it may pull it over on to itself. For scalded throat, give a little cream to drink, or butter if there is no cream, or salad-oil. Send for the doctor without losing time, for the throat may swell and the child suffocate. Until the doctor comes make the child breathe through a sponge soaked in hot water and wrung dry, and put fomentations or poultice on the outside of the throat if the scald is inside.

For a scalded foot, cut off the boot and stocking, do *not* pull them off, or you may pull the scalded flesh away too. Put the foot into warm water. This relieves the pain and keeps out the air. If the doctor does not come, put on oil and cotton-wool, and bandage lightly. Support the foot and keep it well up. Treat the child for the shock to the nerves. In bad cases, brandy may have to be given, but avoid it if possible, and give strong, hot tea or coffee.

If a child has sucked matches and you find it out, perhaps because you can smell the phosphorus of the matches in the breath, *send for the doctor at once.* In the meantime try to make it sick. Put a finger or a feather down its throat, or give mustard and water to drink, or strong salt and water. If you have nothing handy, at least give it a cup of milk. But if it has been sick and is very cold and pale, give it hot coffee and keep it warm. On no account give oil to a child who has sucked matches, for oil causes this poison to be more easily absorbed.

But we must be careful to avoid such accidents, by having the fireguard on, and by not leaving matches, lamps, candles, or pails of boiling water where children can reach them. When children first begin to walk they may pull themselves up by holding on to a tablecloth belonging to a table on which stands a lamp, and may bring the lamp down on themselves if care is not taken. Other things we have to be careful about are all sharp and pointed things, such as scissors, knives, pins, needles, and broken glass. We need to be very careful concerning the floor when baby is crawling about, especially if it is cutting its teeth, for then it particularly loves to put everything it can into its mouth. Sometimes a child chokes itself in this way. When that happens, it may cough so violently that the thing is forced up again, and we can often help by patting sharply on the back. But if the child turns black in the face and is evidently suffocating, we must put our finger down its throat at once and try to hook up

the object. The mere fact of trying to do this may make the child sick, and the act of vomiting bring the thing away. If we still cannot get it up, and the doctor does not come, we can hold the child up by its feet and slap the back hard.

If things get into a child's eye, it is wiser to get a qualified person to get them out, one who can turn the eyelids, and who will not inflame the eye by rough treatment. But if we have learnt well how to do it, we may separate the eyelids, and, looking into the eye, see the tiny speck and remove it with the corner of a clean handkerchief. If the eye is not rubbed, the water which collects in it will very likely wash the trouble away after a little time. When the pain is very bad, and nothing can be done, it is best to put on a little pad of cotton-wool and a bandage, to keep the eye from moving about, and to take the child to someone who is qualified to attend to it. Pure castor-oil is safe to put in the eye and lessens the pain from gritty objects.

If a child swallows something sharp which is likely to hurt the bowels, we should give stodgy food. Give plenty of potatoes, bread, and thick oatmeal porridge, until the thing is likely to have passed out. In these cases we must not give opening medicine.

When a child falls and breaks its leg or arm, send for the doctor, and keep the limb quiet until he comes. If we drag or carry a child about who has a broken limb, we may make matters much worse. If we have learnt "First Aid," we can perhaps put on a splint very carefully to keep the leg or arm stiff and in position before moving the patient. But it is often wise to do nothing but keep the child quiet and prevent the limb from twitching until the doctor comes.

Children should be taught to blow their noses and use pocket-handkerchiefs properly. At table they must be taught not to snatch and not to hurry over their food, and the spoiling of a child's digestion and health, by letting it have whatever it wants, must never be begun. A child must understand from the first that "yes" is "yes," but that "no" also means "no." And those who look after a tiny child need to learn to be wise themselves, and to mean what they say, and not forbid a thing one day and allow it the next.

From the very first we should try to get a baby into sensible regular ways. We can teach a young child to dislike dirt, to be modest, clean, and regular in its habits, to control its temper, to be brave and not cry at every tumble and every little pain, to be kind to animals, and unselfish to other children. Gentleness, wisdom, kindness, watchfulness, firmness, and patience are all virtues needed in looking after babies and young children.

In all our lessons, whatever they have been about, whether we have talked about the skeleton, or about the heart, or digestion, or if we

have spoken of the house, the village, or the country, we have always been learning that we are all members one of another. If the citizen cells in the body do not do their work properly, then the whole body suffers. If one or more members of a family do not lead the lives they ought to lead, the whole family may have to suffer for it. And if the members of a nation do not do their duty, the whole nation will suffer for it also. The British nation is spread over the whole world in the British Empire; the children of to-day will be the men and women of to-morrow; let us all cheerfully do our share in the world's work. The nation more than ever now needs faithful citizens, faithful to God, faithful to the Empire, faithful to each other, and faithful to themselves. We need to discipline ourselves to habits of obedience, self-sacrifice, temperance, and devotion to duty. We are not going to be shirkers, always longing for a soft life. Whatever our hand finds to do, we will make up our minds to try to do it with our might. It is not so much the failure to do a thing, as the failure not to have *tried as hard as we could to do it*, that matters. We will take a pride in feeling that life, in giving us difficulties to overcome, is really asking us whether we are true men and women or only *poor imitations.* We shall do our best to show that we are not unworthy of the land to which we are proud to belong.

For we belong to an Empire whose sons have laid down their lives in thousands that we might live safe and free. We must be worthy of this sacrifice, and we shall indeed be contemptible if we do not do what we can. Our work may be simple, but it is a part of a great whole; and in any case we must be faithful in small things, before we are found worthy to do the big ones. Failure to do our best, that is the saddest failure in life. Unselfishness, cheerfulness, courage, firmness, kindness, generosity, proper respect for our bodies and our health, self-discipline and self-control, these will bring happiness to ourselves and others. We shall go far if we think of the words which King George addressed to us all at the beginning of the greatest war the world has ever known, and,—as good citizens of our glorious Empire,—bear ever in mind the thought,

"DUTY OUR WATCHWORD."

APPENDIX.

All the work mentioned in this book is designedly simple, and the apparatus and materials can easily be obtained or improvised. A few hints may, however, be of use to those who may have had little exercise in the use of some common objects of the chemical or physical laboratory.

Bunsen Burner.—This will be found far more convenient to work with than a spirit-lamp, provided that the nearest gas-bracket is not so far away as to necessitate an inconveniently long rubber-tube to connect it on. Burners can be bought at any laboratory supply shop. Spirit Bunsen burners can also be obtained and are very powerful, but they are expensive, costing from 8s. to 30s. and more. Glass spirit-lamps with a capacity of 8 ounces cost about 1s. 9d., but great heat cannot be obtained from them.

To use the Bunsen Burner.—When a non-luminous flame is required which will produce no soot, see that the ring at the bottom of the burner is so turned that the holes are completely open. *To light.*—Turn on *first* a *full* current of gas, and then, and not till then, hold a match about two inches above the top of the burner. Unless this is done, the gas will ignite below and you will not get your flame right. If you want a luminous flame, limit the air supply by turning the ring so as to close the holes.

Glass Tubing.—Soft glass tubing is easily cut, and can be bought of various sizes. You will want a small triangular file. Lay the tubing flat, decide the length you desire, and then make a short, deep, even scratch across the tube. Lift, grasp the tube from above in both hands, and, putting your thumbs on each side of the scratch, very close to it, gently snap the glass. The rough ends can give nasty cuts and scratches; smooth them by putting them into the flame, turning them round and round till you see a yellow colour.

Caution.—If glass does not break easily, *do not use force.* Make a deeper cut and try again. With a fairly large tube, or if the tube is of hard glass, wrap first in a piece of cloth. Hard glass tubing requires special treatment to manipulate, and you will not need to use it for the experiments given in this book.

To bend Glass.—Use a gas-burner which gives the ordinary flat flame, or a Bunsen burner with a flat flame. Use the yellow, luminous flame. Make up your mind where the bend is going to be, and hold the tube in both hands from above if you wish for a right angle. Place the part to be bent in the yellow flame, and roll the tube between the fingers and thumbs of both hands, so that the part heats evenly. When you see and feel that it is soft and ready to bend, take it out and gently press until you get the shape you want. Hold bends, when made, at the top of the flame, so that they may be covered with soot, and therefore cool slowly and evenly and not crack. To bend at an acute angle, hold from underneath and heat through a greater length than for a right angle. Draw first on paper the shape of your angle, and compare by holding over as you bend. Never bend before the tube is thoroughly ready. The bend should be full bore and the tube not flattened or deformed, and if put on an even surface should lie with its parts all touching that surface.

To Filter.—Take a circular piece of porous paper and fold it across in half; fold it again ; this quarters it. Open it in the form of a cup. It will have one thickness on one side and three on the other and will fit neatly into the funnel. Saturate with clean water, unless it is a matter of no moment whether it absorbs any of the liquid you wish to filter. Do not pour a liquid out into the filter hastily and carelessly. You will probably break the soft saturated filter paper, and the unfiltered liquid will pass through the breaks or between the paper and the funnel, and your work will have to be done over again. Hold a glass rod inside the funnel and pour the liquid gently down it. That which remains behind on the filter paper is called the *residue* or *precipitate.* The liquid which passes through is the *filtrate.* You will find a 4-inch filter paper and a 4½-inch funnel useful sizes.

Heating.—In heating glass vessels on a tripod over the flame, use underneath the vessels a square of wire gauze. A sand-bath gives a high, even temperature, and is merely a *shallow* iron or tin pan filled with dry sand, and heated over the flame on an iron tripod. The vessel you are heating should be slightly embedded in the sand.

In boiling liquids in a test-tube in the flame, it is safer to use a holder. Heat evenly, and hold the mouth of the tube so that no hot liquid can fall on your hand. Never put hot glass or hot vessels on a cold surface. *Dilute all acids copiously before pouring down a waste-pipe, or you will injure the metal of the trap.* If you spill an acid, neutralise with an alkali, or *vice versa.* Observe great cleanliness in all experiments.

Experiment with Carbon Dioxide and Limewater.—The name lime-water is popularly given to a solution of calcium hydroxide, and when

it comes into touch with carbon dioxide, the two interact. The following formula represents the simplest form of what takes place :—

$$\underset{\substack{\text{Calcium}\\\text{Hydroxide.}}}{Ca(OH)_2} + \underset{\substack{\text{Carbon}\\\text{Dioxide.}}}{CO_2} = \underset{\substack{\text{Calcium}\\\text{Carbonate.}}}{CaCO_3} + \underset{\text{Water.}}{H_2O}.$$

Again, the simplest equation for the interaction of hydrochloric acid and carbonate of lime, or *chalk*, is—

$$2HCl + CaCO_3 = CO_2 + CaCl_2 + H_2O.$$

COMPOSITION OF INSPIRED AND EXPIRED AIR.

	Inspired Air.	Expired Air.
Oxygen	20·96 vols. per cent.	16·03 vols. per cent.
Nitrogen, with traces of argon, crypton, etc.	79 ,, ,,	79 ,, ,,
Carbon dioxide	0·04 ,, ,,	4·4 ,, ,,
Water vapour	Variable	Saturated
Temperature	Variable	Same as body
Organic matter	...	Small amounts

From the above it is seen that expired air contains more CO_2 (carbon dioxide), more water vapour, less oxygen, is of higher temperature, and contains harmful organic impurities.

Quantities of Air required.—Dr De Chaumont showed by experiments that whenever the CO_2 in the air of inhabited rooms was greater than that of the outside air by 2 parts per 10,000 of air, or 0·2 per 1000, the air becomes stuffy and unpleasant, from the impure organic matter and moisture given off by the bodies, clothes, and breath of the persons present, so that the 0·2 per 1000 vols. above the outer air is taken as an index of the limit of impurity given out by respiration which can be allowed without injury to health.

Each person on an average gives off 0·6 (3 times 0·2) of a cubic foot of CO_2 per hour, therefore it follows that the air he breathes out must be diluted with 3000³ feet of fresh air.

To find the amount of fresh air required per hour, divide the amount of CO_2 exhaled per head by the amount of CO_2 allowed, less the amount already present in fresh air, *i.e.*—

$$\text{Amount required} = \frac{0{\cdot}6^3 \text{ ft.}}{0{\cdot}6 \text{ ft.} - 0{\cdot}4} = \frac{0{\cdot}6}{0{\cdot}2} = 3000 \text{ vols}$$

With three people in a room—

$$x = \frac{1\cdot8}{0\cdot6 - 0\cdot4} = \frac{1\cdot8}{0\cdot2} = 9000.$$

Size of Openings for Ventilation.—The size of openings required to admit 3000^3 feet per head per hour is determined by the fact that we, in this country, feel as an unpleasant draught a current of air travelling at a greater rate than 5 feet per second. An opening of 24^2 inches, with air travelling at 5 feet per second, will admit 3000^3 feet per hour.

$24^{2\prime\prime} = \frac{1}{6}$ of a square foot, since 1 square foot equals 144 square inches.

It is evident that 24 square inches $= \frac{1}{6}$ of a square foot, since 1 square foot $=$ 144 square inches. Therefore if $\frac{1}{6}$ of a square foot enters every second with a velocity of 5 feet per second through the opening provided, then, there being 3600 in an hour, the problem may be stated as follows:—

$$x = 3600 \times \tfrac{5}{6}^{2\prime} = 3000^3 \text{ feet.}$$

The square being multiplied by the velocity, the product is in cubic measurement.

Measurements.—The area of a triangle equals the base multiplied by half the height. To obtain the cubic contents, multiply by the length. This applies to an attic with a sloping roof.

Recesses in a room must be measured separately and added, while projections must be subtracted.

The area of a circle is obtained by multiplying the square of the diameter by 0·7854; and the cubic contents by multiplying the area by the height.

BIBLIOGRAPHY.

The bibliography of the subjects dealt with in the body of this book is enormous, and no attempt has been made to do more than indicate a few useful books not needing any technical knowledge for their comprehension. Of this type also many more could be added. With one exception, all the books mentioned are low in price.

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